

Technology and Innovation as Cost Reduction Drivers at Teck

by

David Mark Richards

B.Sc., Camborne School of Mines, 1981

M.Sc., Queens University, 1983

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Approval

Name: David Mark Richards

Degree: Master of Business Administration

Title of Project: Technology and Innovation as Cost Reduction Drivers at Teck

Supervisory Committee:

Dr. Ian McCarthy

Senior Supervisor

Professor and Canada Research Chair in Technology and Operations Management

Faculty of Business Administration

Dr. Elicia Maine

Second Reader

Associate Professor, Technology and Operations Management Faculty of Business Administration

Date Approved: July 16, 2015

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Abstract

The purpose of this paper is to analyze the cost control and productivity problems facing the mining industry and Teck Resources in particular, and examine whether technologies, such as automation, and innovations such as integrated operations can contribute to their resolution. The paper identifies the industry that Teck operates in, examines the commodities Teck produces, and identifies some of the problems Teck and the industry faces using a strategic analysis process.

For Teck to shift the paradigm of productivity from incremental evolution to a more productive future, major innovation is a better strategy. The Rock Factory concept, where mining becomes a more continuous operation in order to improve productivity, is used as an example of transformational change. To drive transformation across the organization an innovation strategy and appropriate organizational structure with senior management support is required. Change Management strategies are examined that can be used to successfully implement these strategies.

Keywords: Teck; Technology; Innovation; Change Management

Dedication

Thank you to my wife Jacqui for supporting me throughout the long years of the GDBA and then the MBA program. Your help as a sounding board and with reading years of assignments kept me going.

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Table of Contents

Approval.....	ii
Partial Copyright Licence	iii
Abstract.....	iv
Dedication	v
Acknowledgements	vi
Table of Contents.....	vii
List of Figures.....	ix
List of Acronyms.....	x
Glossary.....	xii

Chapter 1. Introduction	1
--------------------------------------	----------

Chapter 2. The Cost Imperative	3
2.1. The Mining Industry and Teck.....	3
2.2. Industry Definition.....	5
2.3. Open Pit Mining	7
2.4. Industry Dynamics	10
2.5. The Need to Change	18

Chapter 3. Improving Value through Technology and Innovation	21
3.1. Culture – Is Teck Ready for Innovation?	21
3.2. Continuous Improvement versus Innovation	23
3.3. Rock Factory	24
3.4. Technology Strategies	29
3.4.1. Why Teck Needs a Technology and Innovation Strategy	29
3.5. How Do We Change?	33
3.6. Innovation Opportunities.....	34
3.6.1. Mine to Mill	34
3.6.2. Grade Engineering®.....	36
3.6.3. Autonomous Mobile Equipment	38
3.6.4. Integrated Operations	39

Chapter 4. An Implementation Strategy	41
4.1. Establishing a Sense of Urgency	45
4.2. Establishing a Powerful Guiding Coalition.....	46
4.3. Creating a Vision	48
4.4. Communicating the Vision	49
4.5. Remove Obstacles to the Vision.....	51
4.6. Creating Short Term Wins	52
4.7. Sustaining the Change	54
4.8. Make it Stick – Institutionalizing the Change.....	55

Chapter 5. Conclusion.....	57
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References	59
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List of Figures

Figure 1: Teck - Organization of Selected Business Units - Source Author	4
Figure 2: Flowsheet schematic for mining process - Source Author	8
Figure 3: Mining Costs for New South Wales Open Cast Coal (2008) - adapted from Marsten (Meister, 2015)	9
Figure 4: Advanced technology trends compared to other industries - Adapted from Teck Technology Conference (Peck, 2011).....	11
Figure 5: Value Chain - Source Author, based on Porter, 1985	12
Figure 6: Decreasing Feed Grades - Adapted from Dr Gavin M Mudd, Monash University, 2015 (Mudd, 2015)	13
Figure 7: Trends in relative Multifactor Productivity for Australia - Adapted from BREE, 2013 (as cited in Bye, 2014)	14
Figure 8: Porter's Augmented Five Forces - Source Author based on Porter, 1979.....	15
Figure 9: Teck's Technology Centres - Source Author	22
Figure 10: Polar Diagram Comparing Mining & Manufacturing - Source Author	25
Figure 11: Polar Diagram Comparing Mining and Farming - Source Author	26
Figure 12: Innovation matrix - Adapted from Ernst & Young, 2014	32
Figure 13: Value driver tree for Mine to Mill – Adapted from Burger & Dunne, 2005.....	36
Figure 14: CRC-ORE summary of Technology Risk vs. Realization Time - Adapted from CRC ORE, 2014	37
Figure 15: Kotter's 8 Steps to Change Management - Adapted from Kotter's Change Management Process (Kotter, 2007)	42
Figure 16: Alignment of ADKAR model with Kotter's 8-steps –adapted by author.....	44
Figure 17: Commodity prices – adapted from Teck Resources Annual Reports	45
Figure 18: A Potential Organizational Structure for Innovation and Operating Excellence– Source Author	47

List of Acronyms

AMIRA	Australian Mineral Industries Research Association
ART	Applied Research & Technology
B	Billion
BC	British Columbia
BCM	Bank Cubic Metres
BHP	BHP Billiton Ltd.
BREE	Bureau of Resources & Energy Economics, Australia
CapEx	Capital Expenditure
CEMI	Centre of Excellence for Mining Innovation
CEO	Chief Executive Officer
CIO	Chief Information Officer
CMIC	Canadian Mining Innovation Council
COO	Chief Operating Officer
CRC ORE	Cooperative Research Centre for Optimising Resource Extraction
CR4	Concentration Ratio in an industry
EVP	Executive Vice President
FMG	Fortescue Metals Group
FMI	Freeport-McMoRan Inc.
GE	General Electric Corporation
GM	General Manager
I&OE	Information & Operating Excellence
IOC	Integrated Operation Centre
IP	Intellectual Property
KPI	Key Performance Indicator
Mt	Million tonne
MTG	Mining Technology Group
M2M	Mine to Mill
NPV	Net Present Value
OEM	Original Equipment Manufacturer
OPEC	Organization of Petroleum Exporting Countries
OpEx	Operating Expenditure

OTM	Original Technology Manufacturer
R&D	Research and Development
ROI	Return on Investment
SVP	Senior Vice President
SX	Solvent Extraction
t	Metric tonne
Teck	Teck Resources Limited
VP	Vice President
WIIFM	What's in it for me

Glossary

Change Management	The application of a structured process using a set of tools and techniques to manage the people-side of change to achieve a desired business outcome. Change management targets leadership within all levels of an organization from executives and senior leaders, to line supervisors (Prosci Inc, 2015).
Continuous Improvement	A process of continually improving products, services or processes.
CRC ORE	Grade engineering® - increasing plant feed grade
CR4	Measures the total market share of the four largest firms in an industry to create a concentration ratio.
Hypogene	Deposit of primary mineralization occurring deep below the surface and usually occurring as sulphide minerals.
Innovation	The act of introducing something new to an organization such as concepts, devices or methods.
Price taker	A company that must accept the prevailing market price for its products, while its own transactions are unable to affect the market price.
Supergene	Deposit of secondary mineralization occurring at or near surface leading to oxidation and weathering of the minerals.
Technology	The application of science, especially to industrial or commercial objectives.
Triple bottom line	An accounting framework with three parts: social, environmental (or ecological) and financial.

Chapter 1. Introduction

The purpose of this paper is to analyze the cost control and productivity problems facing the mining industry, and Teck Resources in particular, and examine whether technologies such as automation and robotics as well as innovations such as data analytics and integrated operations can contribute to their resolution. I will use a strategic analysis process to identify the industry that Teck operates within and the commodities it produces whilst also identifying some of the problems it and the industry as a whole face at the present time. The goals and objectives of Teck in regards to our approach around leveraging technology to overcome obstacles and be a cost reduction driver for the company, will be examined in greater detail. In addition, I will examine change management strategies that could be used to successfully implement these strategies. It should be noted that innovation doesn't necessarily require sophisticated or new technologies; often they can be adapted from other mines or industries.

The remainder of this paper is divided into four chapters:

- Chapter 2, The Cost Imperative - I explain in detail the problem and make a case why Teck should take a more pro-active approach to innovation in order to improve productivity and reduce costs across the mining value chain.
- Chapter 3, Improving Value through Technology and Innovation - an analysis of the opportunities is presented and I introduce some options and justify an appropriate response to the cost imperative. A case for what needs to change at Teck is presented, detailing a solution and the nature of the change.
- Chapter 4 - An Implementation Strategy - a plan for how and when the change would be implemented. It focuses on change management issues and explains in some detail, with specific reference to Teck and this initiative, how the change would be implemented.

- Chapter 5 - Conclusion - where I stress the importance of making the change and highlight some of the implications of not attempting to change, and/or trying to change without properly planning and implementing the change.

Chapter 2. The Cost Imperative

This chapter will provide a brief overview of Teck Resources, the business that it's in and position in the global mining industry. I will discuss the industry dynamics and the challenges that mining and Teck face. In doing so, I will detail major cost issues and related productivity gaps.

2.1. The Mining Industry and Teck

Mining is an integral part of the global economy; the revenue of its top 40 companies is over US\$700 billion and, according to some figures, drives over 45% of the world's economy directly and indirectly (VCI, 2014). It is the largest part of the economy in 70 developing countries and contributes over half of Australia's export earnings and 20% of Canada's export earnings (VCI, 2014). The mining industry is generally a capital-intensive business, although some commodities still see considerable production from small-scale producers. In the last decade or so, the world's top mining companies such as BHP Billiton, Rio Tinto and Vale have climbed away from the rest (Statista, 2015) mainly on the strength of industry consolidation and the commodity boom (especially iron ore). These three have demonstrated oligopoly power in iron ore – forcing a change from long-term contracts to spot pricing – yet the Chinese steelmakers have also flexed their market power to influence pricing. While this power struggle is happening directly in the iron ore market, it has significant impacts on the steelmaking coal market. With the mineral boom of the last 10 years or so, there has been significant growth in mineral consumption and production (Teck Resources, 2014) even as prices reached unheard of levels. The size of these large companies provides them with the financial strength and the influence with suppliers to drive fundamental changes in the way they operate in their own organizations. While the last year or so has seen the lustre come off the business as markets have tightened and prices softened (primarily as a result of

continued supply expansion), these large companies have continued with their innovation plans while also driving cost control.

Teck is the largest diversified mining company based in Canada with a market capitalization of US\$10.1B (Google, 2015) but on a world-scale rates as a medium sized company. The company is involved across the spectrum from exploration to smelting, including acquiring, developing and producing minerals. Teck's operating interests are in Canada, the USA, Chile and Peru with exploration programs in other countries including Mexico, Namibia, Turkey and Ireland. Production units are focused on metallurgical (steelmaking) coal, copper, zinc & lead and the future energy unit (see Figure 1). While Canada is only ranked 6th globally as a metallurgical coal producer (World Coal Association, 2014), Teck is the second biggest producer of seaborne metallurgical coal after BHP (Teck Resources, 2014).



Figure 1: Teck - Organization of Selected Business Units - Source Author

2.2. Industry Definition

Teck operates 11 mines – six metallurgical coal operations (in BC and Alberta), three copper mines (one in BC and two in Chile) and two zinc mines (in the US), as well as having a 22% share of the Antamina zinc/copper mine in Peru; all but one of these mines are open pit mines. The open pit mining and minerals industry is a capital-intensive business; operating large mines costing \$1B to \$5B or more to develop. Larger companies with a number of mines generally produce a range of minerals, providing a degree of diversification and risk reduction from exposure to one product.

Metallurgical coal prices reached record levels during 2011 (Hill & Loh, 2015), mainly because of China's dramatic increase in production of steel in recent years and, to a lesser extent, demand from other markets such as India and floods in Australia. While thermal coal and metallurgical coal have different properties and markets, the recent exceptionally high prices for metallurgical coal has encouraged steel companies to modify their processes to be able to use cheaper blends of coal; mixing low-grade with high-grade metallurgical coal to reduce the overall cost. Prices have since declined precipitously primarily due to expanding production exceeding the rate of expansion of consumption. Chinese imports totalled 62.3 million tonnes in 2014, down 17.3 percent over 2013, and in the first two months of 2015 they were down 13.6 percent over the same period in 2014, according to Chinese customs data (Russell, 2015). This has resulted in companies becoming very cost focused in order to stay in business, and, except for those with low-cost assets, there is little spare cash for capital renewal.

The demand for copper continues to be met by the discovery of new orebodies although the grade of these deposits continues to drop (30% grade decrease from 2001 to 2012 (Blamey, 2013)). With the boom in mining and subsequent price rises for steel, fuel, etc. and new mine construction being focused in a few countries, OpEx and CapEx costs have grown astronomically. The relative difficulty of finding new orebodies, especially in geopolitically stable parts of the world, has further increased costs as new mines are developed in less accessible and more politically unstable parts of the world.

While copper prices have been equally as high as coal in comparison to historical norms, there appears to have been less ability for substitution because customers

(smelters) have few options and demand for copper metal is still good. The current drop in prices will probably benefit end users of copper more than it does the smelters. Zinc and lead have not benefited from the big commodities boom of the last 10 years, although markets for both have been good. Like copper, these metals are sold to smelters who have little room for substitution themselves although a large percentage of lead is recycled. Coal and copper producers especially have significantly increased production as a result of the higher prices of recent years.

The primary area of substitution for raw materials is the use of recycled material (steel in the case of coal). Higher prices tend to encourage recycling, especially where the material comes from diverse sources, as with copper. Currently, recycling is probably at a high of around 95% for lead (ILA, 2015), 25% for zinc (IZA, 2015), 35% for copper (ICSG, 2014) and 37% for steel (Rubach, 2013). As prices rise, end users (manufacturers and consumers) have greater incentive for substitution; although not all is due to the high metal prices but often to other pressures, such as environmental constraints. Car manufacturers have taken to using thinner, ultra-high strength steel (and aluminum and carbon fibre) to reduce weight and as a consequence zinc galvanizing has become more important to reduce corrosion (McCallion, 2014). Similarly, while most electrical wiring uses copper wire, there are opportunities in some applications to substitute aluminum wire, such as in high voltage lines (Thrash, 2015). With the massive expansion in copper usage, there has been a considerable search for substitutes; plastics in pipe for example. However, demand has proved relatively in-elastic for copper and steel as they offer superior properties to the substitutes. Thus, many of these substitutes tend to be used more at times of shortage, high price, or niche application rather than as a general replacement.

Customers for mineral concentrates produced at most mines are primarily smelters, often located in areas of heavy industry. Mines are located worldwide, where the minerals are found, rather than in convenient locations near customers, and thus logistics are very important in order to overcome geographic disadvantages. Where mines are fortunate to be close to ports and customers, shipping costs are much lower. Customers are similarly located across the globe with shipping distances varying from a few kilometers to many thousand. While customers historically grew up close to mines,

today minerals tend to get shipped long distances to customers in the Far East and, to a lesser extent, Europe, India and the US. Teck faces this challenge both with its steelmaking coal mines being far from the port along a single rail line and the smelter in Trail being remote for customers and suppliers.

The vast majority of production across the sector is from large operations, with a few companies dominating production of each mineral: often the same companies dominate across multiple sectors. This level of concentration reflects, in part, the scale required to achieve a high utilization of capital equipment: industry rationalization is likely to continue as smaller players struggle to compete effectively. This rationalization also provides the dominant players an opportunity to exert a degree of control over pricing and supply; but, as OPEC has shown, this can be hard to manage.

2.3. Open Pit Mining

Teck is primarily an open pit mining company, where the extraction of mineral bearing rock is from large extraction pits accessed from surface. Generally the level of mineralization (grade) in a metal mine is low and thus economies of scale are critical to profitability. For coal, the waste to coal ratios are often high, resulting in large volumes of waste rock being moved for each tonne of coal. Mined ore is generally sent to a concentrator where the ore is crushed and ground in mills for upgrading concentrate by flotation (gangue removal) prior to shipping. Similarly, coal is usually washed to remove impurities (ash) prior to shipping to customers.

The open pit mining sequence of drill, blast, load and haul is little changed over many years. Large diameter holes (150 to 330mm) are drilled by electric or diesel powered drills, in specially designed patterns to optimize blasting. Explosives are loaded in each hole according to design parameters and blasted to create rock fragments able to be loaded by diesel or electric shovels into haul trucks. Waste rock is hauled to waste dumps for long-term storage and reclamation, while ore or coal is hauled to the crushers for further size reduction. There has been little change in the mining process since the adoption of trucks to replace trains in the 1960s, other than the scale of the equipment.

With the long life cycle of these assets (10-20 years or more), the time to implement new technologies and innovations can be significantly lengthened.

After crushing, metal ores are fed to grinding mills for further size reduction prior to flotation and concentration to produce a product for sale. Each of these steps uses increasing levels of energy to reduce the material size; new innovations such as improved blasting provide the opportunity to reduce energy consumption. Figure 2 gives a schematic of the overall process and the mine's part in this.

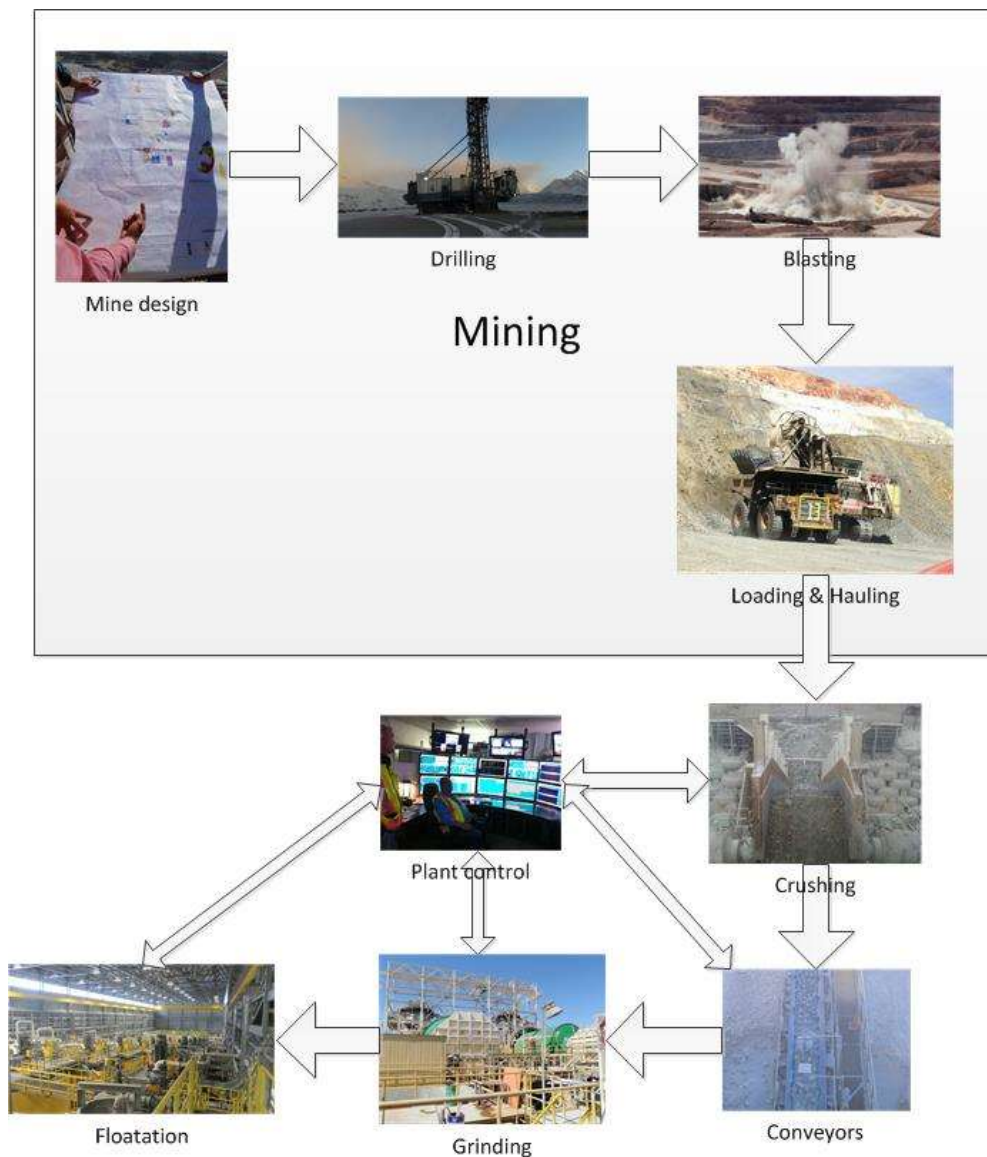


Figure 2: Flowsheet schematic for mining process - Source Author

To give this some scale, an orebody with a grade of 0.4% copper would be considered quite average for an open pit and a strip ratio of 1t:1t is typical. Thus half of the material mined goes straight to the waste dumps as barren rock, the concentrate shipped is generally 25 to 40% metal and thus only about 1.2% is shipped to the customer (Teck - internal, 2015), while the rest ends up in the tailings impoundment. Coal mines can have strip ratios upwards of 7BCM:1t and can be considered almost a waste moving operation (Teck, internal, 2015).

As shown in Figure 3 below, labour and energy is a large proportion of the overall cost in a typical mine. Given the large cost increases that mining has seen over recent years, automation is increasingly attractive. If we are to improve the cost structure and productivity, manpower reduction and energy optimization are attractive strategies. Furthermore, a major benefit of a well-planned and implemented technology and innovation program is better cost management and a reduction of risk and variability (Loehr & Hemmingway, 2014). Risk is reduced by minimizing the presence of people and controlling access to hazards, while processes are optimised to be predictable, with variability in inputs and outputs minimised.

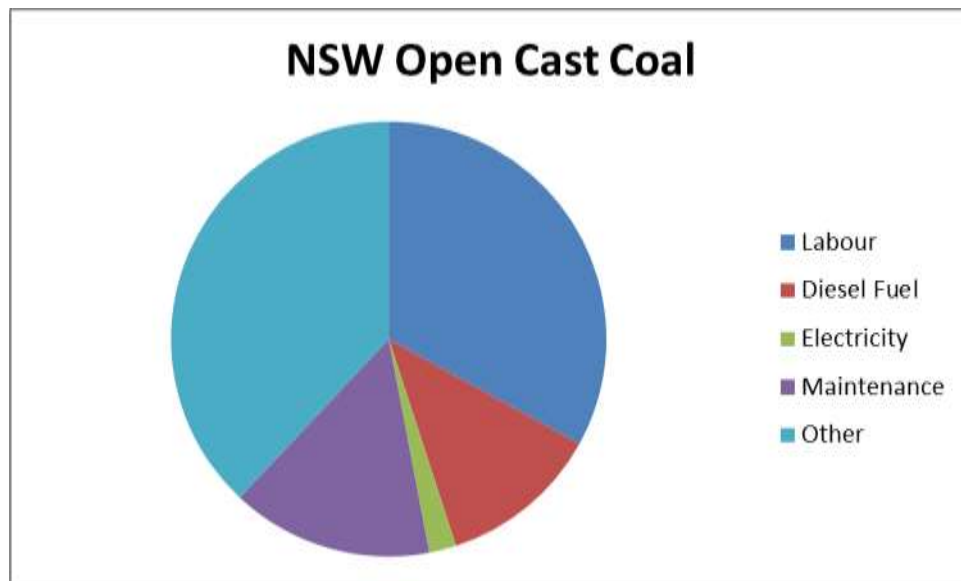


Figure 3: Mining Costs for New South Wales Open Cast Coal (2008) - adapted from Marsten (Meister, 2015)

2.4. Industry Dynamics

How do firms create and sustain a competitive advantage in this industry? There are two basic types of advantage – cost leadership or differentiation (Ghemawat, 2010). Companies try to identify which activities contribute to cost leadership and differentiation, and the sources of competitive advantage. These can include operating scale, access to ports and labour, resource quality, climate, geography, innovation and political stability. Operating efficiency and controlling input costs are key drivers in cost leadership. There is limited ability to differentiate the product, although some characteristics, e.g., cleaner ore than competitors or coal blends that meet a coke maker's needs, can be a competitive advantage when seeking buyers. Many producers have strong sustainability commitments which help differentiate themselves and are important for reputation, sales, access to reserves and ability to hire, etc. Companies compete to buy mineral deposits which are unique; better grades, locations and metallurgy are worth paying for.

The equipment supply chain for the industry is primarily through a limited number of large equipment suppliers/ manufacturers and their dealers. Differentiation is on the contracts that can be negotiated, which in general are associated with volume and stability of orders.

A key characteristic of the mining industry is that several firms can be considered to be homogenous oligopolies with large mines and considerable barriers for smaller players to enter. Many companies have also merged over the years to create economies of scale. There is little control over price and a limited ability to differentiate products and thus scale (volume) is used to control cost and market supply. While there are many competitors in all four of Teck's product areas, in times of low price, high cost producers are forced from the market. While increasing demand for minerals is expected to continue to drive increased production, there will be a greater focus on cost and productivity as prices are expected to remain under pressure (Teck, forecast, 2015). Dependence on China creates a vulnerability in pricing and demand especially during a downturn.

How does this affect the introduction of technology and innovation? Since most mining companies are selling commodities, margins are usually slim and product

differentiation is not very viable, thus cost leadership is the only way to survive in a normal market. Mining is a marginal business, and unless there is a clear business rational, a research project, perhaps with a questionable probability of success or undefined/unclear return on investment, is seen by some as a waste of money. Furthermore, in a business environment in which companies are more interested in short-term production capacity than in the long-term competitiveness that could potentially result from innovation, getting funding for research is often difficult both from the industry and government. However, in the UK, technological advances aided by collaboration between firms, universities and government have allowed manufacturing to become more efficient, increasing productivity 56% between 2008 and 2014 (The Economist, 2015). It is apparent that the large companies (Rio Tinto, Anglo American, Vale and BHP for example), although they are not all advertising this, are pursuing advanced technology strategies (Figure 4). They have recognized that in order to remain cost competitive and in business, this is a necessity. These companies have deeper pockets than most of their competitors and can reap a massive return from an improvement as small as 0.1% at their scale of operation.

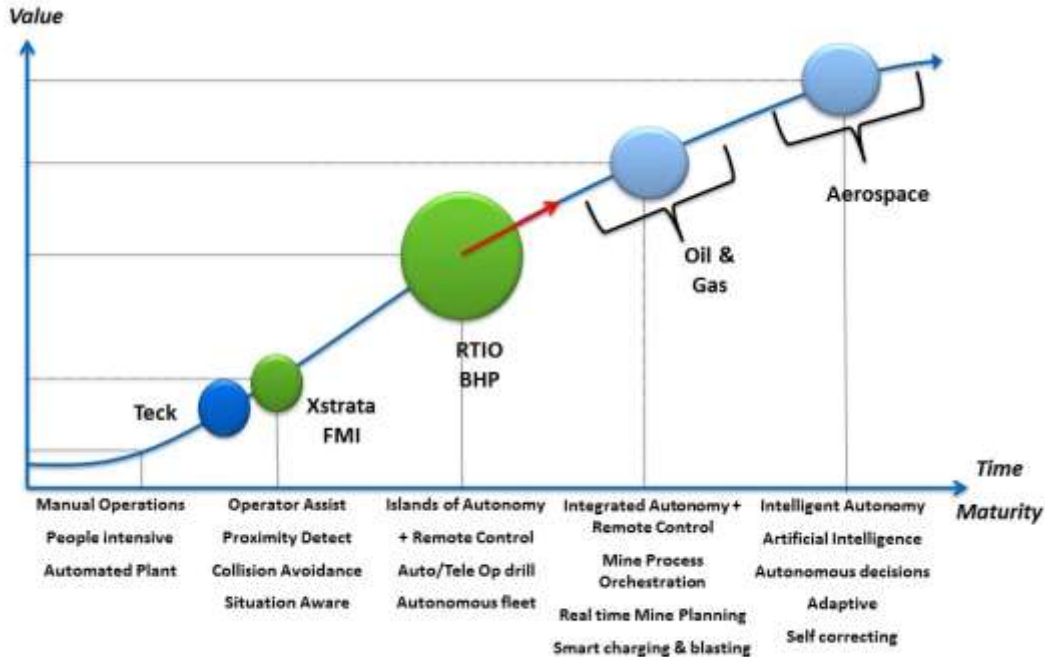


Figure 4: Advanced technology trends compared to other industries - Adapted from Teck Technology Conference (Peck, 2011)

Looking at the mining value chain (Figure 5), we can see that the primary activity focus in this industry is on operations to produce mineral output at as low a cost as possible while meeting quality, safety, environmental and other goals. Secondary activity foci include the acquisition of sufficient mineral reserves and efficient logistics for shipping product to meet customer demand. The importance of marketing and sales depends on the mineral being produced but the majority are sold through long-term contracts rather than the spot market. Sales focus is on differentiating product through attributes such as reliability of delivery, product blend through market segmentation and quality control.



Figure 5: Value Chain - Source Author, based on Porter, 1985

Support activities include the purchasing and maintenance of a great deal of mobile and fixed equipment as mines are capital intensive. Similarly, they require skilled and semi-skilled employees to operate them. Technology development has in large part been limited to increasing the scale of operations and equipment to raise productivity; technology and innovation have not been seen as important in themselves. Procurement management is essential to maintain relationships with suppliers and manage contracts ensuring the large volumes of supplies required are acquired at the best prices with little acknowledgement of the importance of innovation or technical capability.

Until the last 10 years, the industry had been characterised by decreasing feed grades (Figure 6) and prices, forcing mines to focus on costs and efficiency. With the recent commodity boom in 2010 to 2012, there was a change in focus in many companies to produce as much product as possible almost to the marginal cost. This resulted in many lower-grade mines being opened and existing operations lowering the economic cut-off grades. As shown in Figure 7, this has resulted in a drastic drop in productivity in terms of output. This boom exacerbated an existing trend to larger, deeper and lower-grade pits, where ever larger volumes of material have to be moved to produce the same volume of saleable product, resulting in a drastic drop in productivity for the industry. This was a conscious choice by companies to get product quickly but not efficiently. Although companies, including Teck, have been able to make a marked improvement in operating costs through continuous improvement programs such as the Teck 'Cost Reduction Program', the real issue is to raise productivity while still being competitive on costs.

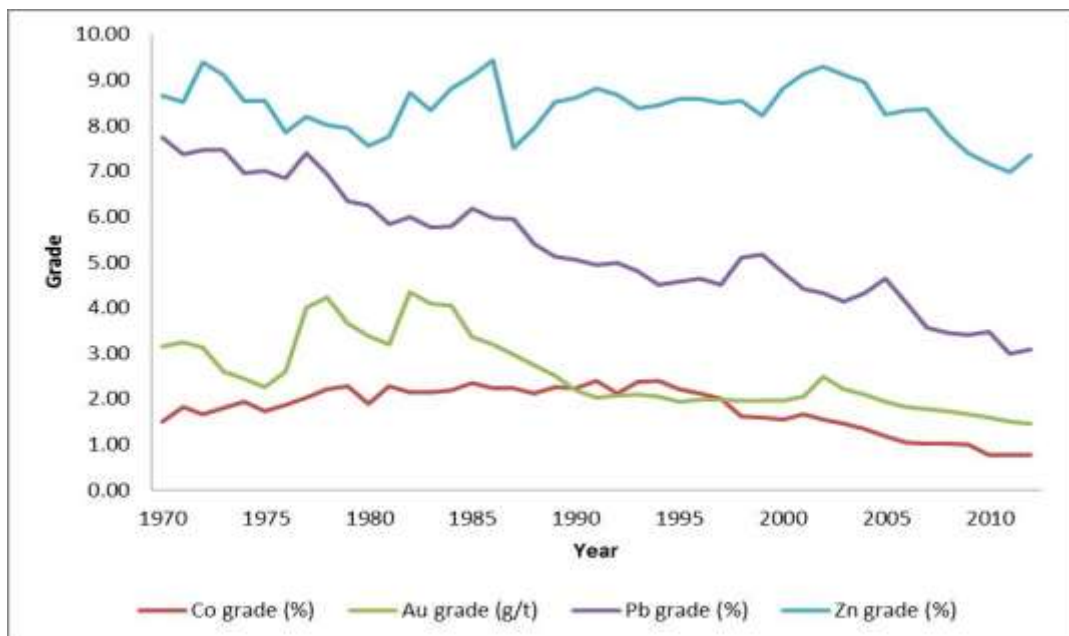


Figure 6: Decreasing Feed Grades - Adapted from Dr Gavin M Mudd, Monash University, 2015 (Mudd, 2015)

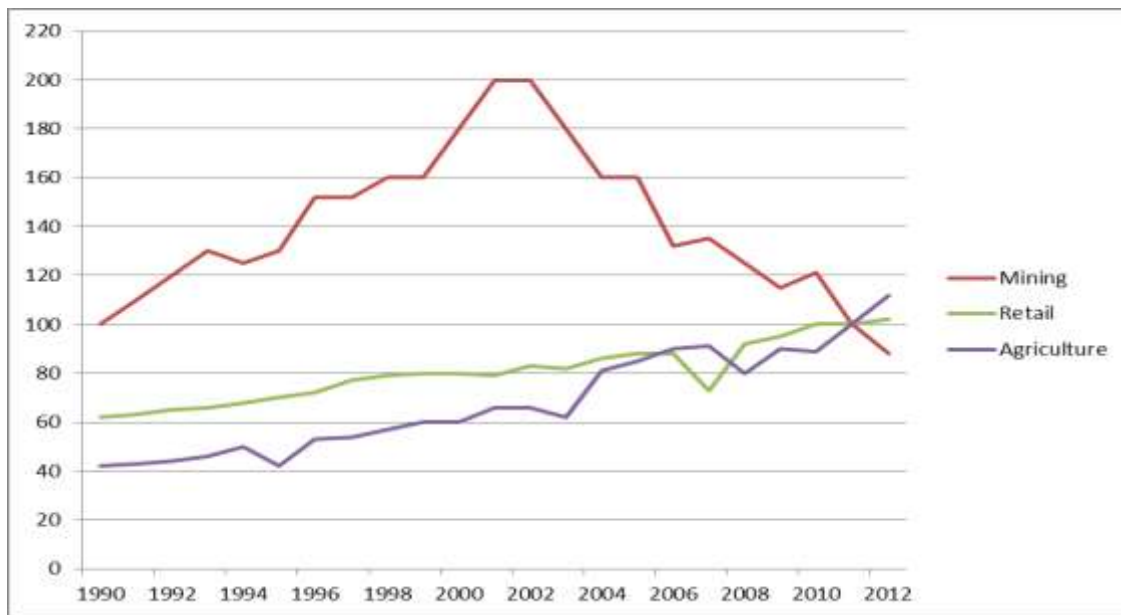


Figure 7: Trends in relative Multifactor Productivity for Australia - Adapted from BREE, 2013 (as cited in Bye, 2014)

Using Porters Augmented Five Forces model (Porter, 1979) to examine the mining industry competitiveness (Figure 8), we can see the following:

Bargaining Power of Suppliers:

- Mining is capital intensive and companies buy most of their large equipment from a handful of large suppliers such as Caterpillar and Komatsu. Mining companies try to mitigate this through the use of supplier contracts and long-term relationships. Suppliers have more power in boom times than in periods of low commodity price.
- The switching cost for companies to move from one equipment supplier to another is often high as they have large fleets of equipment which have long lives and require regular maintenance.
- Suppliers also make more money through spare parts sales over extended periods of time as opposed to the initial capital sale.
- Technology suppliers are generally small but tend to be bought by larger companies if successful. While there has been a trend of equipment suppliers buying technology suppliers, there is also increasing concentration in the

hands of large technology companies like Hexagon Mining, Trimble and GE. While technological innovation by OEMs is driven by customer demand as discussed elsewhere, demand is driven by variables such as market conditions, availability of labour, location, etc.

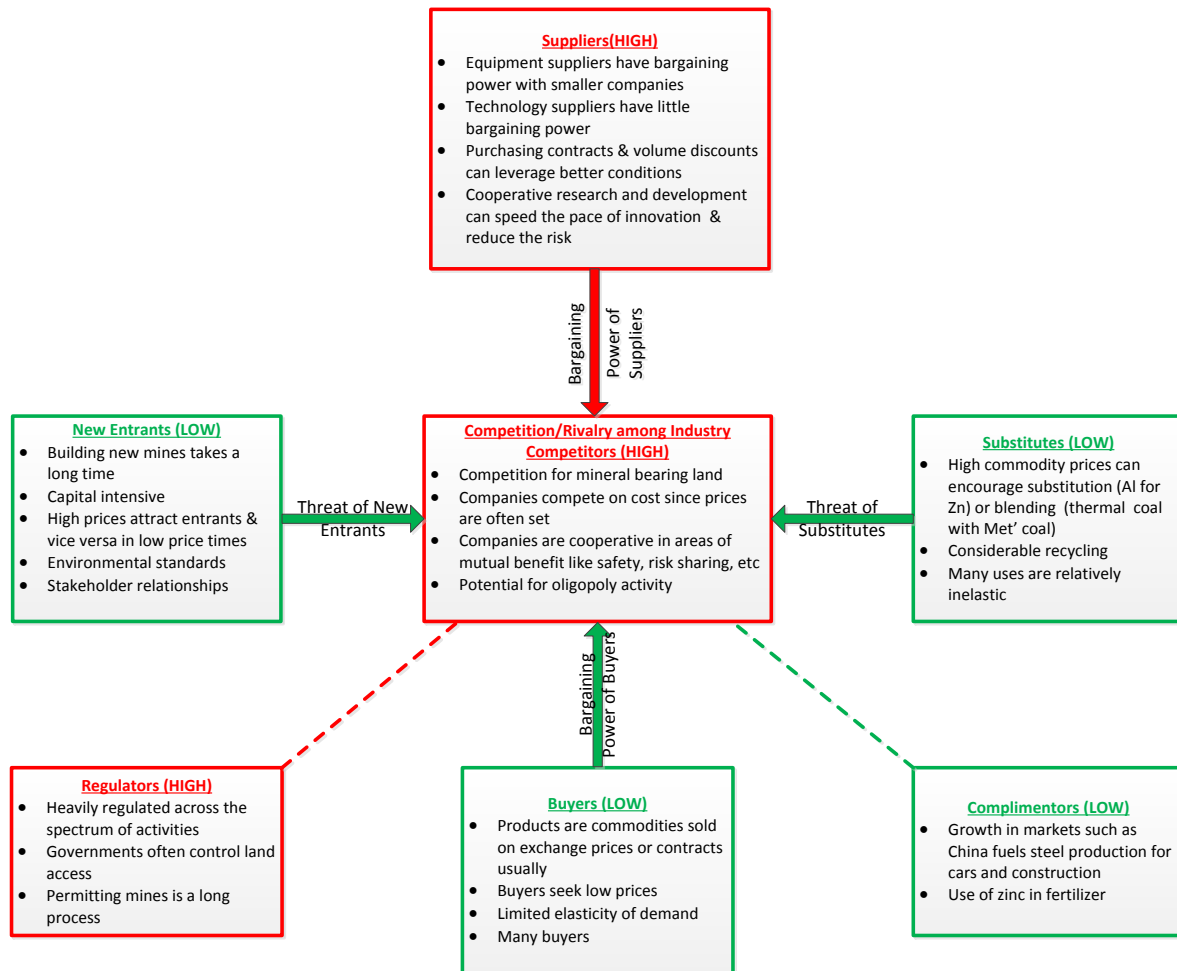


Figure 8: Porter's Augmented Five Forces - Source Author based on Porter, 1979

Bargaining Power of Buyers:

- Minerals are commodities and are sold through long-term contract and the spot market; there is limited ability to enhance value through differentiation other than through blending or product quality.

- Buyers seek lower prices and better contracts; supply and demand drives the price. There is limited scope to influence price through reducing supply.
- Buyers are generally not concentrated in buying groups although the Chinese government is thought to exert influence when prices get too high or low.
- There are few direct substitutes for smelters and steel makers although consumers and manufacturers have some choice.

Threat of New Entrants:

- Lower commodity prices reduce the attractiveness to new entrants while high prices (such as in the recent boom) increase attractiveness.
- The industry's capital intensiveness is a high barrier to entry.
- Finding and building new mines takes many years (or even decades).
- Brownfield expansion can be a more cost-effective way to increase capacity. Social License to Operate is an increasing barrier to entry as well.
- Exploration is often in the hands of junior companies who then sell out to larger companies who exploit the resources.

Threat of Substitutes:

- High commodity prices encourage substitution by users (example aluminum for steel) or blending lower performance coals with metallurgical coal.
- High prices encourage recycling; as discussed above while recycling percentages in some metals can be high, the market is growing, leading to increased overall demand.
- Normally, there is little incentive for substitution as many products have other advantages that the market desires (e.g. copper pipe versus plastic), making demand relatively inelastic.

Competitive Rivalry:

- Companies compete on cost since prices are often set by exchange pricing or contracts; product differentiation is low. Mergers are sometimes preferred over new development. Joint Ventures are a commonly used vehicle to reduce barriers to entry that also reduce competitiveness.
- The concentration ratios (CR4) are; copper 32.7% (Bell, Copper, 2015), zinc 22.9% (Bell, Zinc, 2015), lead 15% (ILZSG, 2015) and seaborne metallurgical coal 31% (Anglo American, 2014; Teck Resources, 2014; Rio Tinto, 2014; BHP Billiton, 2014) - oligopolies are possible especially in copper and seaborne coal.
- Companies will sometimes collaborate in areas of mutual benefit such as safety, infrastructure and the development of technology.
- Companies compete to acquire deposits either through exploration or purchase.,

Regulators:

- Getting mines permitted can be a long and difficult process.
- High government involvement in mining from land ownership, through permitting to operations and closure/reconciliation.
- Social licence to operate includes not just government but First Nations, communities, etc.

Complimentors:

- Economic growth in markets such as China fuels steel production for cars and construction.
- Agricultural growth uses more fertilizer and additives such as zinc.
- Increasing fuel efficiency is reducing steel usage but increasing the need for zinc galvanizing.

2.5. The Need to Change

A spate of recent reports characterise the mining industry as having ‘an accumulated deficit of transformational innovation (Ernst & Young, 2014) and highlights ‘the slow pace of innovation in mining’ (Visser, 2013). A survey from Virtual Consulting International (Stanway & Andrew, 2013) revealed that, while 100% of mining companies interviewed regard innovation (doing new things, utilizing technology and increasing business value) as important in reaching their objectives, 81% do not have a formalized approach to implementing innovation, and 62% said that their innovation efforts were either ad-hoc or non-existent. Where does Teck want to be on the innovation curve to meet its business objectives?

The ability for mining companies to change the way they conduct their business has been restricted by a decade or more of companies slashing their capacity for research and development. While there are many examples of innovative ideas and technologies in the mining sector; such as autonomous trucks and drills at Rio Tinto’s Pilbara mines, and FMG’s use of Surface Miners to replace drilling and blasting (also in the Pilbara), it is widely recognized that overall the industry does poorly on innovation. As Mark Cutifani from Anglo American (Leach, 2014) noted, this is partly due to a lack of investment but it is also partly the industry’s mindset. Mining is a conservative industry with many inherent risks such as politics and commodity prices, and innovation is seen as a risk that can be avoided.

Obviously, the state of the mining industry has a significant bearing on the willingness of the industry to invest and in what direction. For example, when fuel prices are high, the focus is on reducing energy costs and dependency on fossil fuels but when the industry is booming and quality labour is hard to get, expensive automation to replace people is the favoured direction. Thus the appetite to fund particular technologies is often cyclical like the commodity industry as a whole, rising and falling accordingly. As a case in point, autonomous trucks were hot (and will be again) but currently users are focused on making the best out of the capital assets they already have, adding operator assist and safety systems. Capex is harder to get and leveraging Opex to get incremental improvement rather than step changes is easier.

The problem then becomes how does Teck focus on the appropriate technologies and innovations? Challenges that would benefit from technology and innovation include:

- Safety - What role can technologies such as machine autonomy play in the drive for zero accidents by limiting the exposure of personnel to hazardous conditions?
- Dropping ore grades - How can technology help to improve the identification of new orebodies and improve the quality of existing quality of ore reserves despite the decline of average grades?
- Increasing unit costs - What role can technology play in reducing costs and ensuring greater efficiency in the mining and processing of ore while also having a lower environmental footprint, as easily-mined near-surface ore bodies become exhausted?
- Fundamental change - In order to remain viable it will be necessary to look at new and innovative ways of finding, mining and processing ores.
- Managing change - We need to create a culture that is receptive to change across the entire mining value chain and all stakeholders.
- Big data - The key to using data is deciding what the problem is, harnessing the data by turning it into actionable information and rapidly sharing it so that can be used for accurate and timely decision making.

While many sectors such as aerospace, automobiles and even farming have found that most successful innovation comes from something outside your industry being applied to your own (Dubner, 2015), mining companies see their business as being different to others. These industries have transformed themselves using these new and borrowed ideas and thus have greatly increased productivity, while mining has been reluctant to change. Mining companies are under pressure to return cash as dividends, probably because investors don't see mining companies using the money well in terms of growth or productivity and cost control. If we look at what other businesses sectors have done, increasing investment in research on innovation amongst other areas has the potential to radically change the economics of mining.

Ultimately, it is important to understand that Teck needs to be a leader in operational efficiency if it is to effectively compete against competitors with lower distribution costs. We will never get an order of magnitude increase in NPV through piecemeal changes; big changes require a holistic approach. Since these problems are universal to all companies, I will examine what others are doing and see how these alternative strategies could be adopted by Teck (Ghemawat, 2010).

Chapter 3. Improving Value through Technology and Innovation

In this chapter, I will discuss the current level of innovation in Teck and ask if the company is ready for a strategy that would help advance technological innovation to shift the paradigm of productivity from historical incremental evolution to a more productive future. I will compare continuous and incremental improvement with major innovation and show that if we want to be transformational, major innovation is the path we need to take. I will discuss the Rock Factory concept where mining becomes a more continuous factory-like operation in order to improve productivity. I will then discuss why we need an innovation strategy if we are to drive change and innovation across the organization and how do we change. Finally, I will look at some examples of innovation opportunities and how they can help drive improvement.

3.1. Culture – Is Teck Ready for Innovation?

Teck no longer has a Technology Division or voice in the Senior Management Team for technology – as such, teams are scattered throughout the organization (Figure 9), reporting to various business units and functional groups. In addition, there is also significant ad-hoc work being done at some sites that is not well-coordinated or visible. There are little or no formal processes for interaction, with little communication or coordination of effort. This results in little visibility of the work done in the technology and innovation field by the company as a whole and no voice at a senior level in the management team. If new projects are to look any different to existing projects, there needs to be a voice at the table at each stage of the process and especially in early project stages with a mandate to advocate for innovative technology. In the same manner, there is only intermittent/periodic engagement with the business units which is more dependent on the people involved than a formal engagement process for success.

While the engagement process has improved in recent years, with some operations engaging heavily with groups like ART or MTG, others still have little interaction.

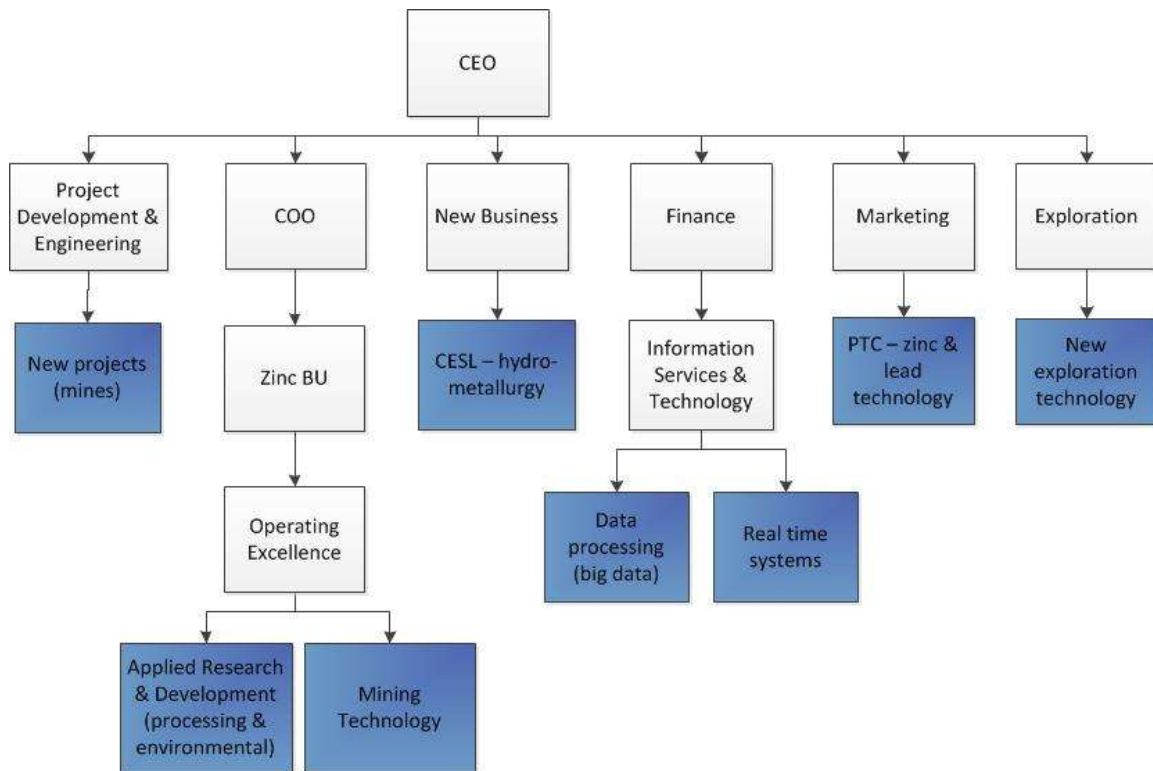


Figure 9: Teck's Technology Centres - Source Author

At a corporate level, Teck is obviously concerned with the viability of its overall portfolio of operations, both current and future. As primarily a producer of commodities, the company is a price taker with little scope for differentiation. Cost control and accurately predicting demand and pricing are critical to effective management. Integrating a capable technology and innovation program into this environment is difficult without a voice at senior level speaking for technology as a portfolio. Having executive support also allows the creation of a strong innovation culture that is receptive to new ideas.

3.2. Continuous Improvement versus Innovation

As a means of controlling costs and improving productivity at its operations, Teck has adopted a process of Continuous Improvement (or Business Improvement) across the company. The process provides a means of prioritizing improvement efforts and reinforcing value as a core principle of management activity. The focus of most projects is on small easily-managed improvements that, while far reaching at times, are incremental to the existing processes rather than game changing. While these improvements may require both an innovative thought process and perhaps the application of new technology, they are not generally looking at fundamental shifts in the way we do business. The focus in a climate of volatility and declining commodity prices tends to be on Continuous Improvement-type initiatives; however, the competitive advantage that can be achieved from implementing new and innovative (and perhaps proprietary) processes is well understood (Stanway & Andrew, 2013). These advantages tend to arise from innovative technologies rather than traditional economies of scale.

Small increments in the way we do business can differentiate successful producers from loss makers in a traditionally low-margin business. However, in general, these advantages are transitory as they are not patentable or the advantage is captured by a supplier. Thus, producers are continually striving for incremental improvements if they are to stay ahead of the pack.

A different level of opportunity exists for companies who can create proprietary technologies or processes that can be protected as proprietary innovations or implemented through the use of a skilled workforce. Some, like Rio Tinto, have decided that there is economic advantage in going it alone on the development and implementation of new technology and innovation, seeing strategic value through the (assumed) competitive advantage that is enabled. Others, like Anglo American, see advantage in spreading the cost and risk of technology through collaborative research and development and widespread adoption of the outcomes.

Teck has a history of both collaborative research and working alone to preserve secrecy. Teck has participated in collaborative research programs with organizations such as AMIRA as well as directly with other mining companies such as Barrick Gold.

For a smaller company like Teck, the ability to spread the risk and minimize cost while getting the benefits of a larger program are substantial. However, when there is a benefit to maintaining our own IP, Teck has gone it alone with projects like the copper products and indium and germanium SX processes in the 1990s (Defrayne, Parker, & Stradling, 2005).

The value proposition of innovation and technology can be improved by ensuring the right intellectual property strategies are adopted, much as we protect physical property through ownership and legal rights. Even in a proprietary development environment, much of the work is done by collaborators of one sort or another and it is important to ensure that ownership and exploitation rights are fully protected.

3.3. Rock Factory

The idea of a mine as a rock factory has been put forward for several years now as a solution to the poor productivity issue (Hemmingway & Loehr, 2014). This envisages using 'big data' to create a factory-like continuous operation; this could be analogous to an underground longwall coal mine, where rock is continuously cut and conveyed to surface. However, if we look at a polar diagram comparing mining with manufacturing (Figure 10), we can see that, while some things are aligned, others are very dissimilar. The greatest alignment is around safety, where mining may place a greater emphasis on this element versus manufacturing; in part because of the greater inherent risks. When we apply the analogy to the planning, operation, management and evaluation of the operation, we can see some tremendous opportunities to bring greater technical rigour to the way we run a mine. In manufacturing, there is great emphasis on measuring, reporting, comparing and acting upon data; something that mining has not been good at but that is quite feasible to implement. A factory lives or dies based on the accurate execution of the various processes which it carries out and, in a factory, it is normal to measure even the smallest process. The mining industry faces a number of challenges in trying to replicate these concepts; the most fundamental of which is that rock has a variable structure, hardness, composition, chemistry, etc. Most of these characteristics are only represented statistically in 3D models created from sparse drilling samples.

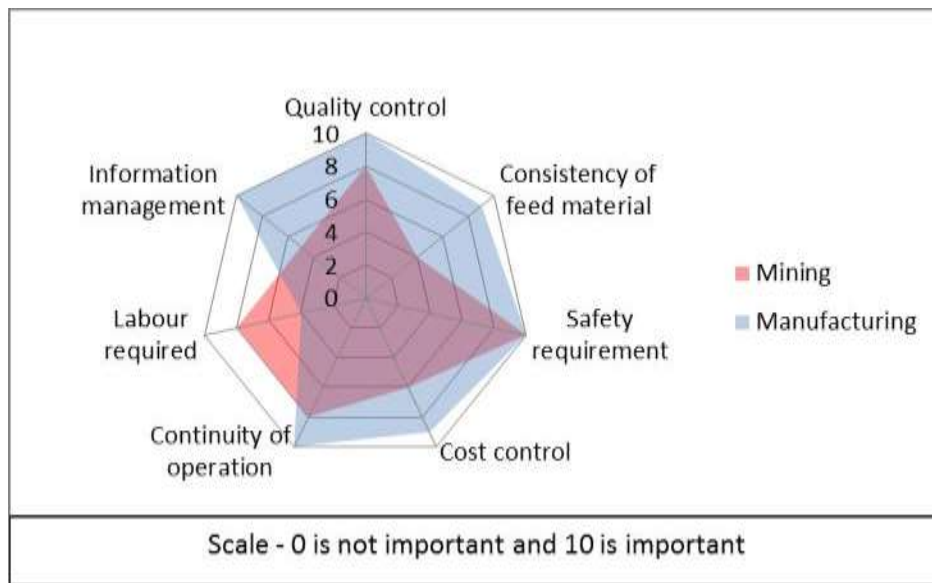


Figure 10: Polar Diagram Comparing Mining & Manufacturing - Source Author

While the plant and processing equipment are designed to process a certain quality of feed, the rock feed from the mine is very variable and so engineers are challenged to blend material to meet the customer's (the plant) criteria. The result is an averaging of a huge number of variables, many of them poorly understood, to create a blended feed that likely does not meet the quality required most of the time.

The way that most mining methods are currently designed is as a batch process (compared to the plant which is continuous). In large part, this is a result of the equipment used, leading to a cyclic series of activities – drill, blast, load, haul - that are often poorly integrated. This cyclical activity is inherently inefficient when applied to a capital intensive operation resulting in low utilization of capital, high cost and poor productivity. While many companies have looked at more continuous processes, there has been little success to date in mining hard rock (compared to softer bedded material such as coal or potash). Furthermore, because of the scale of a mining operation and the amount of ancillary activity required (road construction, waste handling, etc.) which are paid for by the mine rather than supplied as a public good, the labour requirements are large compared to a manufacturing process.

Perhaps a better comparison is with large-scale farming where there has been a massive growth in automation in recent years (Figure 11). The feed material is quite inconsistent like mining but farming has been far more pro-active in measuring and reporting on the inputs in order to better understand what they are growing and harvesting. Cost margins are similarly slim and skilled labour more difficult to get. Safety is one area that mining pays far more attention to, in part because the size of each mine's workforce is much larger and incidents are more widely noted. At the same time, farming has been much more successful in automating many processes in a work place that is very variable. The success in farming has been driven in large part by the shortage of people and the ability of farmers to make and implement the necessary transformations easily.

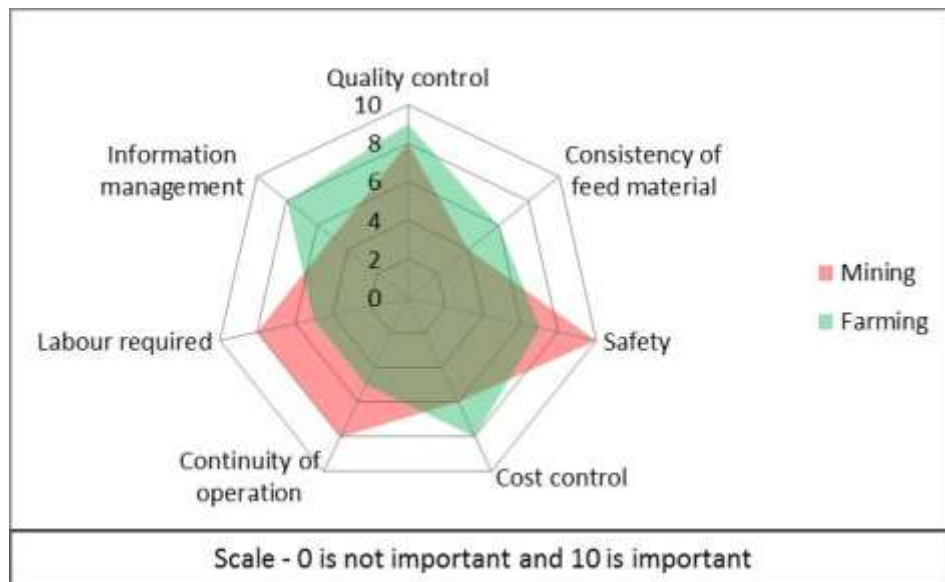


Figure 11: Polar Diagram Comparing Mining and Farming - Source Author

So how has the mining industry done in this area? Fortescue Metals Group (FMG), a second tier iron ore miner, has brought a great deal of innovation to their Pilbara mines in an effort to overcome the lower grades and break the cost advantage that the large companies – Rio Tinto and BHP - have. They have had mixed success in many of their initiatives and have been criticised for not always managing the technical risk adequately. At the same time, however, they have successfully weathered a number

of low price cycles and have grown to a 155Mt per year Company (Fortescue Minerals Group, 2015).

Rio Tinto has also been a big spender in the innovation area (Rio Tinto, 2010) but has chosen to work in isolation in an attempt to gain first mover advantage. They have attracted a lot of industry attention in the direction they have taken and appear to have gained some benefit from trying to keep the details of what they are doing in-house (Rio Tinto, T&I, 2015). Their focus has been on a number of areas including remote operations control, autonomous vehicle control, extracting information from data and bringing ore bodies to production (Mining Magazine, 2015) more quickly. A lot of this has been driven by the circumstances of the Pilbara iron ore fields – low labour availability and high cost, remote location and high cost of supplies. However, they are now applying this knowledge to the wider organization. By going it alone, they intend to get first mover advantage and at the same time delay competitors from achieving the same benefits.

Anglo American had, in common with many South African mining companies, resisted automation and innovation and consequently seen the productivity drop and cost profile soar particularly at its gold mines. Recently, under the new leadership of Mark Cutifani, it has reversed this direction and Cutifani has commented that “we as an industry are woefully under-spending on innovation and business-improvement programs given the state of extraction challenges” (Cutifani, 2013). Anglo has since created a Technical & Sustainability group, pledging \$30M per year, to drive innovation and technical development within the company. In contrast to Rio Tinto, Anglo is taking a more collaborative open-forum approach working with other companies through organizations such as AMIRA and CRC ORE.

While mining companies are starting to recognize the need for greater innovation, equipment manufacturers (OEMs) and technology suppliers (OTMs) are busy trying to get into the market. The OEM's seem to see this as an opportunity to increase market share through exclusive access to their technology, e.g. autonomous trucks only working on one operating system. This runs counter to the mining companies' traditional model of supporting multiple suppliers to ensure competition.

Other industries such as aviation have been through this same scenario, where manufacturers thought they could entice customers into exclusive relationships. Eventually it was recognized that there are greater advantages with open standards and that closed standards are too restrictive. Mining companies have responded with initiatives such as the Global Mining Standards Group (GMSG) that Teck supports. If Teck is to build up its competitive advantage, we need to look beyond incremental performance improvement to work out how we can revise our systems to be more innovative. Peter Bryant from Clareo Partners recently commented that to be successful the mining industry must bring spending on research and development in line with other sectors. “Based on benchmarking of R&D expenditures in other industries, mining companies should contemplate increasing their R&D investments to 2-4% of revenues. It would also be very beneficial for R&D investment by key suppliers in joint projects to increase spending from the current 1% to 3-4%. These levels of spending are consistent with approaches in the oil and gas industry” (Leach, 2014); in comparison, Teck spends approximately 0.2% (Teck Resources, 2014) on R&D.

As mentioned above, many mining companies are supporting some sort of open collaboration model for developing new technology and innovation. Teck has traditionally supported this approach with organizations such as AMIRA, CRC ORE, CMIC, etc. There are a number of advantages to this, not least risk and cost reduction while getting the benefits of a much larger program than most companies could afford on their own. Open Innovation is the latest iteration of this process which lends itself well to these capital constrained times, allowing companies to both spread the risk and increase the opportunity by investing in diverse, value added opportunities. However, the current challenge is how to move from vision to actual execution whereby a clear business case and actionable strategy are essential if this is to be successfully achieved. Collaboration does have a downside in that few companies share confidential information openly and the outcomes can become diluted by multiple objectives.

OEMs and technology suppliers are also sources of new technology in themselves that Teck needs to be constantly evaluating (and challenging) to determine where a competitive advantage can be gained. Furthermore, some technologies are at the heart of Teck’s competitive existence and Teck needs to protect these technology

rights because it provides a further competitive advantage. Ultimately, it is the speed at which Teck can adopt and extract value from an innovation or technology that really determines whether Teck can make use of a competitive advantage, because within a couple of years at best others will have access to the same technology or it will be superseded by a better technology.

3.4. Technology Strategies

Currently, Teck does not have a technology strategy although it has looked periodically at creating one, most recently this year with the engagement of Elizabeth Stroud from Discovery Learning; this analysis is still in progress. The last case study was in 2005 (Teck Resources, 2005) and was conducted internally and led to the creation of a Technology Division and the creation of VP, Technology position. This group lasted a number of years and brought together a number of the technology functions within the company. While apparently successful, it failed to embed the value of technology and innovation in the company and did not outlast its first VP before fragmenting into the current situation (Figure 9).

Other companies have had a mixed response to technology with groups being formed and then later disbanded or amalgamated into operations. Rio Tinto has one of the most prominent technology strategies currently with its Technology and Innovation group, made up of technology centres that identify, share and implement leading practice across Rio Tinto (Rio Tinto, T&I fact, 2015). Anglo American has its FutureSmart™ program working towards finding innovative solutions to its challenges around mining, processing and sustainability.

3.4.1. Why Teck Needs a Technology and Innovation Strategy

Commodity prices had a record run of high prices during the mid-2000's but in some cases have since slid to almost record lows. At the same time, operating and capital costs have risen dramatically to record highs. While there are many reasons for this rise in cost, a common theme is the ongoing drop in orebody grade, deeper mines (open pit and underground) leading to longer transport routes and increased input costs

(steel, fuel, etc.). Ultimately, it is difficult to beat a good orebody in the right location in the competition to keep productivity high and unit costs at a minimum.

Innovation has been incremental rather than step-wise as discussed above; haul trucks and shovels just get bigger but are essentially similar to what were used 50 years ago. Autonomy is the latest incremental change but is ultimately just a temporary step rather than a game changer. Trucks weigh as much as the payload and at least half the time are running empty; this results in a great deal of energy and time being spent unproductively. To make a significant change in productivity and cost, we need to change the way we do things. Sometimes innovations, like the use of Surface Miners by FMG in the Pilbara, prove initially to be very expensive to operate and do not (at least initially) increase productivity. However, the speed at which new technology can improve both in operating cost and productivity with sufficient commitment shows there is potential to change the way the business operates. Other manufacturers such as Joy and Caterpillar are working on continuous miners for hard rock – a difficult application. While FMG have worked with Wirtgen and Vermeer on the Surface Miners, the technical complexity and cost prohibit all but the largest companies such as Rio Tinto and BHP from going alone on a project like this. Even the OEMs are looking for mining companies to work with on this sort of development to ensure there is a customer at the end of the development road (Caterpillar Inc., 2008). The advantage of being involved in basic research and development like this is the ability to not only shape the outcome, but also to understand the value and how it can be integrated into new and existing operations, and therefore become a successful early adopter. The danger as always is if we can all adopt the same technology and equipment, nothing changes and the race to the bottom to be the lowest cost supplier continues and margins continue to be low.

Without a technology strategy, there is no clear guidance for either the technology units or for the operations within Teck. The current situation results in silos of knowledge both within operations, between operations and between technology centres, if for no other reason than poor communication channels. Where technologies have been acquired or developed, there is often sub-optimal technology transfer to users, even with channels such communities-of-practice. Furthermore, especially in a period of limited funds, some project initiatives have limited opportunity to add material value.

A Technology Strategy needs the following elements;

- Integration with the current business strategy.
- Commitment from the board and the executive to execute over the short-, medium- and longer-term.
- A roadmap to tell us where we are going.
- Alignment between corporate and the operations with a common vision.

Execution and Implementation of the strategy requires:

- Communication, endorsement and adoption across the entire company to ensure proper stakeholder engagement.
- The technology portfolio supports long-term growth and development as well as meets the short-term needs for continuous improvement.
- An emphasis on the application rather than the use of technology with a clearly defined business case and justification (ROI) that can ultimately be validated.
- The ability to quickly implement new technology to take advantage of innovation before others can and thus be fast adopters rather than late followers.
- Competencies that support technology transfer, change management, incremental improvement of operational productivity and support of innovative technologies that materially improve the way we run our operations.
- A risk management plan to identify and possibly avoid over extension and achieving a realistic application with the expected ROI.
- A voice in the Senior Management Team and an organizational structure that provides better collaboration and communication between appropriate groups.

Teck (as with many mining companies) is risk averse and tends to stick to tried and true methodologies/strategies when designing new mines or replacing existing equipment. This is due in part to minimizing overall exposure to focus on maximizing

shareholder value and rarely includes technology as one of the key criteria when making such decisions. Even with a clear vision, strategy and pathway, many initiatives generate great ideas but do not lead to viable executable projects. Lack of visible results is the most obvious reason innovation programs falter where clear communication and quick wins help to build support. Thus we need to have a clear strategy that says we will not only include technology when appropriate but that we will be a fast adopter. This strategy needs to be driven from the top as operations are focused on operational efficiency and, at best, innovation is dependent on local levels of management. For innovation to be successful, it's the organization not the technology that's important. When we understand what are we trying to achieve, then the combination of different initiatives and technologies can coalesce to form a cohesive whole.

If we are to effectively innovate and change the paradigm of productivity (**Error! Reference source not found.**), we need to understand where these innovations sit i.e., are they radical or incremental, do they affect a single function or an entire value chain? While all forms of innovation are important, those that change the value chain will be farther reaching and have the potential to create a step change. At the same time, they will be more difficult to implement than those that affect a single function. However, single point initiatives can be unsatisfactory if not well integrated into the whole mining process.

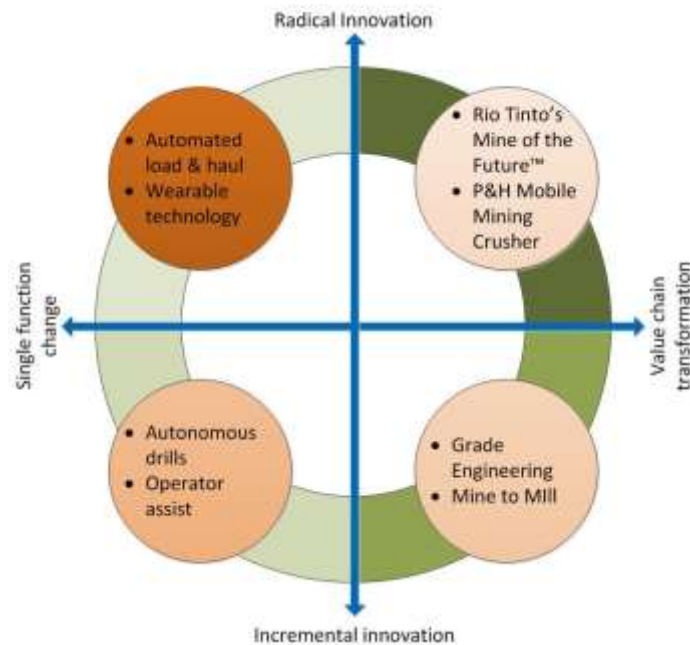


Figure 12: Innovation matrix - Adapted from Ernst & Young, 2014

3.5. How Do We Change?

Why has mining always been reluctant to adopt new technology or innovate? There are many reasons for the reluctance, some of which are discussed above but others include the small size of the mining industry when compared to others such as manufacturing. How many shovels can a company like Joy Global sell in a good year - only 50 (Teck, email, 2015), and the total market for mining equipment was estimated at US\$71.5B in 2012 (PRNewswire, 2014), compared to the \$1.5 trillion automobile market. Mining is a capital-intensive business, often with high levels of risk; investors want to minimize this risk by being as predictive as possible and reducing unknown risks as much as possible. This leads to companies building new mines much as they have built the previous mine, even to the point of Xstrata using a standard plant design that varies solely on the designed throughput tonnage. We only know a limited amount about an orebody based on relatively widely spaced diamond drill holes and perhaps some bulk samples. Mining and processing decisions are based on these limited data sets, often leading to some nasty surprises when production starts. In an effort to reduce this risk, AMIRA created the P843 project and the practice of combining geology, geostatistics and metallurgy was developed to create a spatially based predictive model for mineral

processing. Teck was an early adopter of this technique with extensive work being done at the Red Dog mine to understand the complex Aqqaluk deposit.

If we look at farming as another primary extractive industry, each farm unit is small but the overall scale of the business is huge, with intense cost pressures and a need to constantly reinvent the business to stay ahead. Farming was an early adopter of mechanization as the industrial revolution and urbanisation led to shortages of workers. This has accelerated since the Second World War leading to big gains in mechanisation and more recently automation. As farms have consolidated in size, so have the suppliers of equipment allowing them to reach a size where they can support considerable research and development. Today, a company such as John Deere is a leader in developing automated machinery. The next evolution is likely to come from Australia where labour costs are high and unlike California, there is little opportunity for temporary migrant labour (White, 2015). In Australia, farms tend to be huge and isolated from urban centres forcing farmers to be productive and efficient. Mining is similar with both companies and suppliers consolidating into larger units and intense pressure to increase productivity. For similar reasons to farming, Australia is leading this change because of labour shortages and costs.

3.6. Innovation Opportunities

As discussed above in Section 3.1, technology teams are scattered through the organization with a limited voice and rely on a mix of operations and corporate sources for funding. A technology and innovation approach requires a roadmap that identifies the goal – ‘the mine of the future’ and then defines the steps to get there. Without this overarching program, the opportunities listed below are still orphan projects that do not fully leverage the value of each preceding project. The current model relies on an ad hoc governance process with an evolving prioritization model. Although challenging, there are a number of innovations underway or on the horizon with potential to have a great impact on the company. These include:

- Mine to Mill
- Grade Engineering®

- Automated/autonomous mobile equipment
- Integrated Operations

The lack of a technology and innovation strategy and visibility at senior management levels makes the job of getting any of these opportunities recognized much more difficult than it would otherwise be. Similarly, persuading operations to pay attention to, let alone adopt one of these strategies, is difficult.

3.6.1. Mine to Mill

Mine to Mill (M2M) was developed as an operating strategy in the 1990s for mining operations to improve the performance of mining and downstream processing activities. Since its first implementation, it has been applied across a number of mining applications including open pit metal and coal mining. If properly implemented, M2M provides the full integration of geology, mining and processing functions across an operation with benefits including a better integrated operation with a clear unified goal. Productivity gains in the region of 10-20% are possible while reducing unit operating costs and overall energy consumption. This value chain optimization is possible by focusing effort and cost at the most critical parts of the production chain to achieve overall productivity and cost optimisation. At the same time, M2M improves predictability and reduces the variability of both mining and processing activities providing performance benchmarks for ore types at multiple points and the ultimate ability to deliver the correct specification ore to the plant.

Within Teck, Highland Valley Copper (HVC) was an early and successful proponent mine of the strategy and the mine was a global leader in the field with a number of papers published and wide recognition of its expertise. For a period of seven years from 1998, the mine consistently produced 18% more tonnes than it had historically before reverting back to historical production (Wilson & Richards, 2010). While there were a number of reasons for this regression, the mine recognized the value of the process and has launched a new initiative. While Teck's other metal mines have recognized the value of M2M and are implementing their own programs, there has been little recognition of the potential value within the coal business unit. A value driver tree

(Figure 13) shows some of the important activities for meeting production and allows managers to focus on the critical areas and better prioritize their decisions.

There is a considerable potential value in expanding a version of M2M to the company's six steelmaking coal operations. The value in coal is to reduce coal damage and fines production through reducing the powder factor and optimizing blasting. Getting operations to understand the potential benefits and make the commitment to change is difficult given the scope of the changes required even in the copper and zinc business units; the importance of short term wins on the way to large scale change cannot be over emphasized.

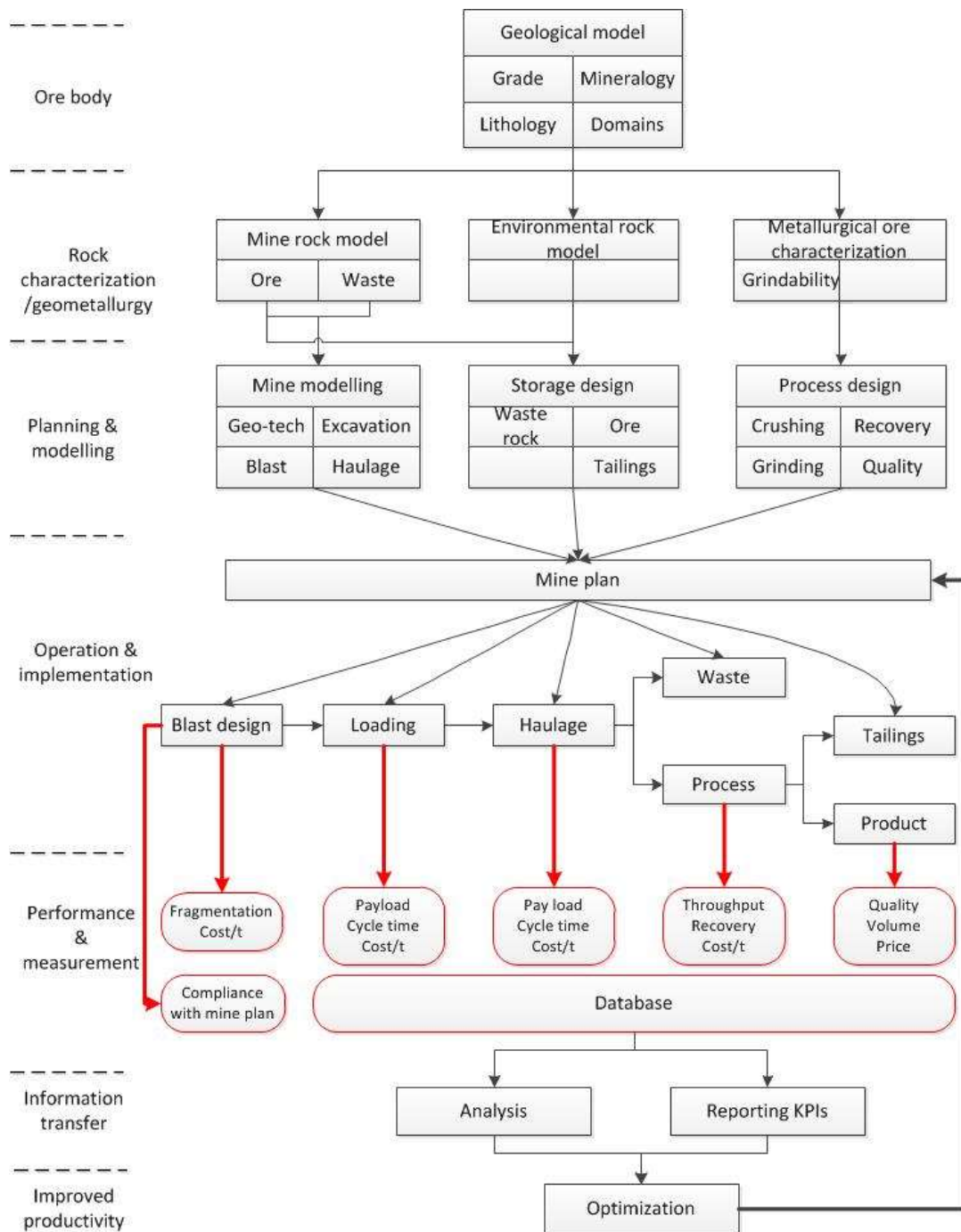


Figure 13: Value driver tree for Mine to Mill – Adapted from Burger & Dunne, 2005

3.6.2. Grade Engineering®

Teck has been a member of the CRC-ORE consortium in Australia since 2011. This is a collaborative research initiative to bring together ore body knowledge, mass

mining, blasting engineering, mineral processing, spatial modelling and resource economics. CRC-ORE has developed an integrated approach focused on maximizing metal produced by removing gangue from the ore stream as early as possible in the mining/processing value chain to reduce the impact of declining grades.

The process uses a number of techniques to exploit ore variability such as differential blasting and ore sorting, suited to a particular orebody's characteristics and the associated plants capabilities to remove waste material as soon as possible in the ore handling process. This integrated approach dovetails well with the M2M process as an incremental innovation to improve mine productivity. Teck, as a sponsor, has preferential access to this technology and through a pre-scoping study has identified a number of strong opportunities among the base metal mines.

In order to realize these benefits, a scoping study will be required to quantify the business cases which, if successful, could lead to one or more project implementations. Although Grade Engineering® will not provide an immediate return on investment, the size of the potential prize at each site is large and estimated to be reasonable in scope (Figure 14). While the value is seen as long or medium term at two sites, the time-scale of the study suggests the value should be identified sooner than later.

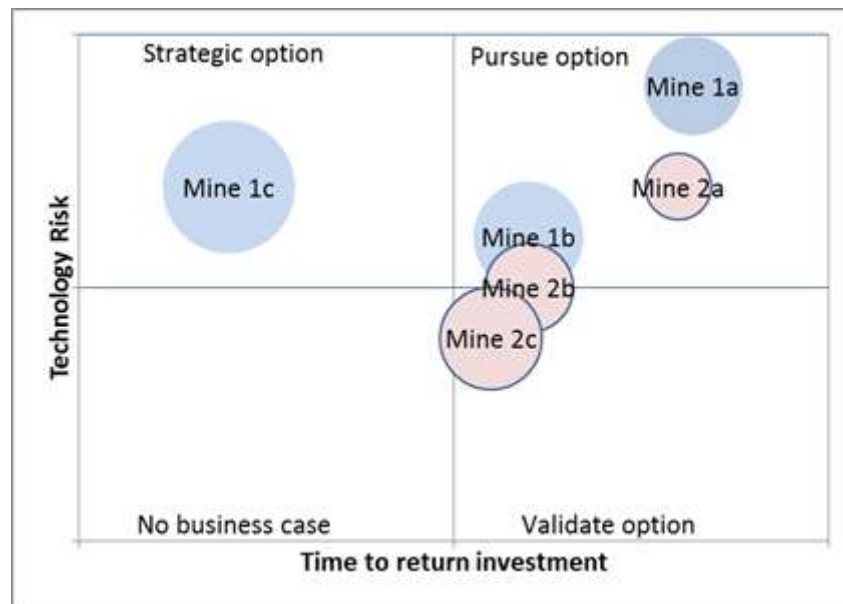


Figure 14: CRC-ORE summary of Technology Risk vs. Realization Time - Adapted from CRC ORE, 2014

The potential value of these initiatives is very significant but, as high-risk initiatives, they struggle to get traction with the mine sites which are constrained in their budgets and have operational imperatives that limit the resources that they can put to what, from their perspective, could be described as blue sky thinking. A clear innovation strategy with strong executive support and alignment with operations and their long-range resource development plans will help realize the value of this initiative.

3.6.3. Autonomous Mobile Equipment

Although many mining companies have adopted automation solutions in certain parts of their operations, the level of automation is extremely low compared to most other industries. A number of companies, like Rio Tinto, have recognized the value that autonomous equipment can bring to improving productivity, increasing safety and reducing costs. Since 2012, Rio Tinto has been in the process of commissioning 150 autonomous trucks across its Pilbara iron ore mines which will result in 50% of production being produced autonomously (Chamber, 2102). Rio Tinto is also operating a number of remote controlled and automated blast-hole drills in the Pilbara. Although the future has been promised several times, it is likely that within five or ten years we will see most new large scale mines and a number of existing ones adopting autonomous haulage and drilling. This is driven by operator shortages, the push for increased safety, higher productivity and reduced costs.

While technologically challenging, autonomy only provides single function transformation whether as a drill or a truck (the two currently most viable solutions). However, as momentum increases, equipment suppliers beyond the original OEMs are increasing their capacity in the automation field which will lead to an expanding product range and capability.

Teck has already dabbled in autonomy with the development of a semi-autonomous drill at Fording River mine. While currently only a prototype, the drill has demonstrated the potential to retrofit existing drills to create a degree of autonomy and provides a potential path forward for fleet-wide remote operations. Potential benefits include greater productivity, increased safety and lower costs.

Provided there is a compelling business and operational case for automation, for Teck to take advantage of these rapidly expanding opportunities requires a clear mandate from the Senior Management Team and support for the early adopters to go with what would still be seen as a risky strategy.

3.6.4. Integrated Operations

Whilst many of the technologies and processes inherent to the Integrated Operations Centre concept may be new to the mining industry, they have long existed in other industries such as manufacturing – where the benefits are well proven over time. The idea of managing the complete integrated process - Value Stream Management – incorporates tools to visualize the value stream and provides a means to measure the integrated process, thereby enabling process improvement and better management of variability. Further, decision making becomes quicker as data can be transformed into real-time management information and reports. Over time, this data capture and transformation can be used to create algorithm-based predictions further improving decision making and productivity.

In the mining context, Rio Tinto has championed the concept of Integrated Operations with its Integrated Operations Centre in Perth which has been emulated by several other companies including BHP, Newcrest and FMG (Crozier, 2013). However, the rationale for Rio Tinto's initiative was based on better managing its logistics chain where a number of mines use a limited capacity rail line. Other considerations included the high cost of keeping people at sites, high labour turnover and skills shortages. Other companies in the Pilbara, such as BHP and FMG, have similar concerns and it makes perfect sense for them to emulate this model. For companies like Teck or Newcrest that operate in a different paradigm, the value of integrated operations is in the increased ability to manage variance rather than remote operations. Although dealing with a different paradigm, Rio Tinto achieved about a 10% throughput improvement through system optimisation of its iron ore operations in the Pilbara (VCI, 2012).

Implementation of an Integrated Operations Centre (IOC) complete with fundamental revisions to the business model is a major project and will require the

highest level of executive commitment. However, a number of Teck operations could benefit from the strategic introduction of elements of the Integrated Operations Centre model. While originally proposed as a solution for Quebrada Blanca – a remote high-altitude mine in Chile, elements of the concept have been introduced at Highland Valley Copper (HVC) where there has been a consolidation of responsibilities into two control rooms and the development of a short interval control process. This is seen as an evolutionary approach - rather than revolutionary - realizing value from each step along the way.

In addition to HVC, opportunities also exist to integrate the mining and plant control rooms at Carmen de Andacollo as well as the originally proposed Quebrada Blanca mine. Teck could also realize great benefits from integrated operations in its mine to mill and geometallurgy programs. Within the Coal BU, there is an obvious opportunity integrating selected services for the five mines in the Elk Valley and even for the Cardinal River operation. An opportunity to demonstrate some of the value has presented itself with creation of a joint fleet management centre for two of the coal mines.

Taken as whole, these incremental and sometimes single function transformations can deliver substantial value improvements, especially where the complexity of managing or optimising the end-to-end value chain often exceeds human capacity.

Chapter 4. An Implementation Strategy

The challenge of implementing major change is fundamentally different than continuous incremental improvement that organizations are currently built to deliver. In this chapter, I will review aspects of the change management process using John Kotter's principles on leading change (Kotter, 2007) that will be required to institutionalize the solutions proposed. I will describe what is required for the successful long-term implementation of new technology and innovation as an opportunity to transform our business. History is full of good ideas and innovative practices that have failed to make a difference in the long term because we failed to manage the change process.

Culture is an integrated system of learned behaviours or habits. Although habits can take years to change, persistent effort toward an effective future can create tremendous value. The change process goes through a number of phases that require a considerable length of time to accomplish and skipping or shortening steps, while creating an illusion of progress generally produces an unsatisfactory result. Consequently, any significant change at Teck will require significant time, effort and commitment across the board from the top down if we are to accomplish a successful reorientation.

As an example, while Highland Valley Copper was an early adopter and successful implementer of the mine to mill (M2M) process, within seven years it had reverted back to the historical production level (Wilson & Richards, 2010). As usual, there are a number of reasons that led to this dramatic change but, in large part, much of it can be blamed on not completing the change management process of consolidating improvements and institutionalizing the new model.

In order to improve the likelihood of success in implementing a technology and innovation strategy, we will outline how the strategy plan addresses John Kotter's eight

steps of transforming an organization (Kotter, 2007). Kotter's article, "Leading Change, Why Transformation Efforts Fail", was originally published in 1995 and outlined eight critical success factors that remain pertinent today to realize success. Each of Kotter's eight steps (Figure 15), as described below, will be examined (Kotter International, 2015):

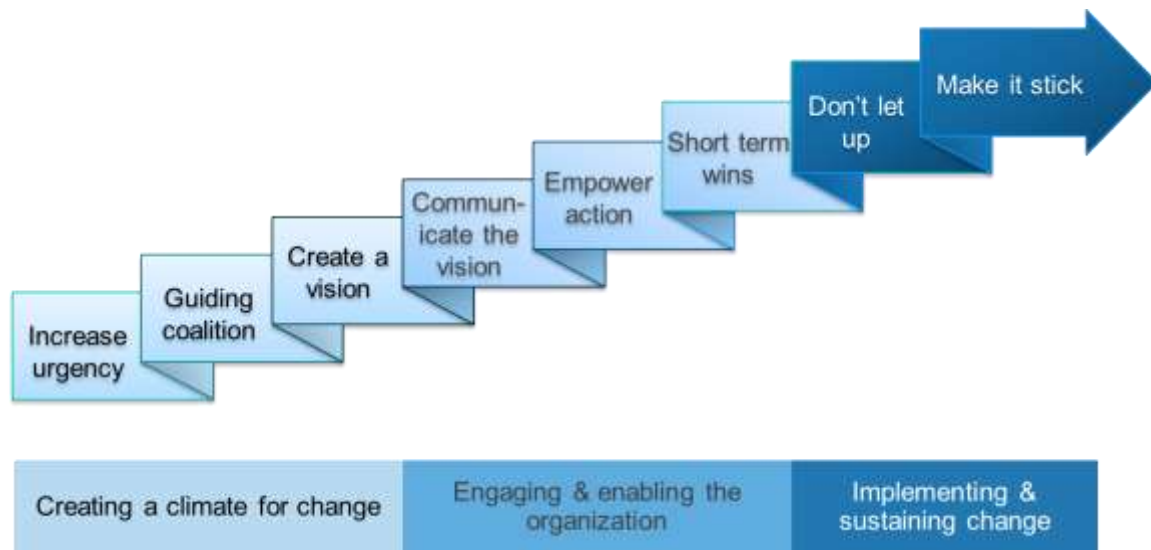


Figure 15: Kotter's 8 Steps to Change Management - Adapted from Kotter's Change Management Process (Kotter, 2007)

- 1 Rather than thrusting a change in the way we do things down the throats of operational managers, we need to create a sense of urgency within Teck corporate and the business units that change is required and that it needs to be transformational if it is to achieve a significant improvement in productivity. Crafting or using a significant opportunity as a means to excite people to sign up to change the organization is often successful if sometimes risky.
- 2 A powerful guiding coalition needs to be formed that brings the right people together at the senior management team level (CEO, COO and Business Unit Heads) to support the vision that we need to be more innovative. This group needs to have the power and energy to lead and support the collaborative change effort.
- 3 What is our vision for the future and what change is needed to realize our vision? Having good easily conveyed answers help the organization to make

the future they want more probable. Shaping the vision to help steer the change effort and developing strategic initiatives to achieve that vision are critical for success.

- 4 Gather a group of people who are ready, willing and keen to drive the change; transformational change projects tend to generate lots of information. It's critical that people understand why change is needed. Communicate the vision throughout Teck using all available communication mediums while keeping the message simple.
- 5 Remove obstacles - change systems or structures that pose threats to realizing the vision. Empowering others to act on the vision as a part of the implementation plan creates momentum and a belief that change can be achieved. Un-empowered people accept what can and can't be achieved internalizing a belief that they are incapable of achieving change.
- 6 Achieving large scale organizational change requires momentum, a sense of achievement, and optimism; creating quick wins by specifically identifying sub-projects that will lead to high profile business improvements promotes longer term success. Tracking and celebrating both small and large successes builds confidence that we are doing the right thing.
- 7 Having developed some early successes Step 7 is about not letting up and continuing to build momentum. Creating the structures and opportunities that empower employees to take risks and innovate to solve problems without fear of negative reaction. Reinvigorating the process maintains momentum building on the early changes.
- 8 Articulating the connections between the new initiatives and organizational success helps to institutionalize the new approaches and create an environment for future success and required changes. Maintaining the transformation requires ongoing effort from management so that people continue to connect the vision with success.

Teck has adopted Prosci's ADKAR® change management model across parts of the company as a tool to help people focus on how to ensure change results in a business success. The five steps of the ADKAR model are (Hiatt, 2006):

1. Awareness – of the need to change
2. Desire – to participate and support the change
3. Knowledge – about how to change
4. Ability – to implement new skills and behaviours
5. Reinforcement – to keep the change in place

The ADKAR model has its origins in traditional change management and provides a framework for management teams to identify gaps in the process and provide effective coaching to employees. The Prosci model fits with Kotter's 8-steps (Figure 16) capturing how a single person goes through change. The time taken for each individual to move through each step will vary; thus we cannot treat the whole organization as an homogenous mass.

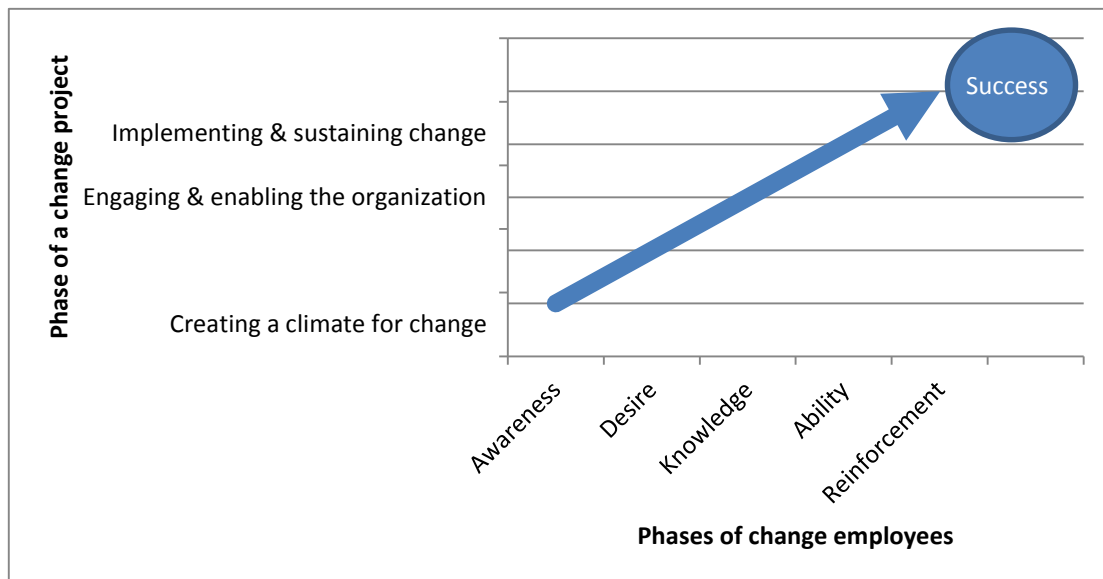


Figure 16: Alignment of ADKAR model with Kotter's 8-steps –adapted by author

Common failures are when more attention is paid to the business change than to the employees affected by the change. The opposite extreme would be when too much

attention is paid to employees and the business result is not achieved, perhaps as a result of extensive resistance from employees. Both are unacceptable; success is achieved when a change is introduced, and employees are given the awareness, and have the desire to implement the change, the knowledge and the ability to make it happen and the process is reinforced to sustain the change (Hiatt & Creasey, 2003).

4.1. Establishing a Sense of Urgency

Until recently, the industry has been characterised by decreasing feed grades (Figure 6) and prices (Figure 17) forcing mines to focus on costs and efficiency, while costs have more than doubled. During the recent commodity boom, many companies increased production at the expense of productivity (Figure 7) and unit cost. While the importance of reducing costs has been driven home through continuous improvement programs, the size of the problem is too large for point solutions to solve on their own as they often have the effect of just moving the problem elsewhere in the process chain. Real and sustainable productivity gains will only come from a broader business revolution.

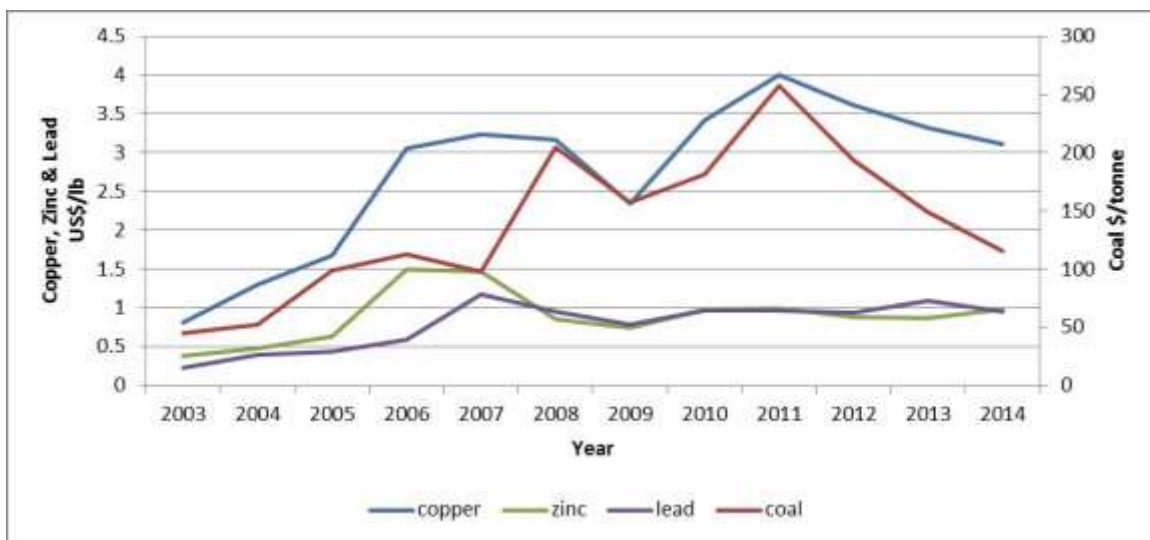


Figure 17: Commodity prices – adapted from Teck Resources Annual Reports

Teck needs to emphatically communicate to the workforce the difficulty of competing if we continue to work the same way we always have. Continuing to operate in the existing paradigm but expecting different results is to fly in the face of reality; as a

famous quote said “*Insanity is doing the same thing over and over again and expecting different results*” (O’Conner & Kellerman, 2013). Portraying the competitive realities in the mining industry will help to motivate employees to achieve higher levels of performance and will be instrumental in eliciting buy-in. Employees need to realize the tremendous opportunity and long term job security that the proposed solutions will create.

In establishing a sense of urgency for transformational change, we also need to openly describe the opportunities that can be created through transformation. Clearly, the current situation in the mining industry with low prices, low productivity and high costs presents the opportunity that can readily be portrayed as a time of crisis. Although during a time of low profits and cost constraint it is difficult to justify resources being put into new technology when the benefits may not be readily apparent, now is the time to initiate a change in the organization that can produce real gains through innovative mining and processing methods. As the major companies bring on new capacity with greater productivity driven by technology, those who do not keep up will go out of business (Section 3.3, page 27).

4.2. Establishing a Powerful Guiding Coalition

While a renewal program such as this may start with one or two people, for successful transformation the leadership coalition needs to grow to achieve a critical mass. Major change of this nature will require support at the highest level in the company including the CEO and COO as well as board approval. To achieve the level of support that will be required, the organization needs to be reformed to bring many of the technology and innovation parts of the company together under one group (Section 3.1), led by a vice president who can guide and influence the Senior Management Team. A possible structure is demonstrated in Figure 18 bringing innovation and operating excellence together in one group allowing a coordinated effort of both incremental and transformative change.

To drive the change will require a guiding coalition; establishing such a guiding coalition involves establishing a steering committee that supports the need for change.

This will initially need to start with the Senior Management Team in Vancouver which includes the CEO, COO, senior vice presidents, VP Innovation & Operating Excellence (I&OE), the Chief Information Officer (CIO) and a number of other subject matter experts, before spreading to the Operations Managers. While not every senior manager will support the initiative, since not everyone will buy in, the coalition needs to be powerful in terms not just of titles but information, expertise, reputation and relationships – in other words it has to have credibility.

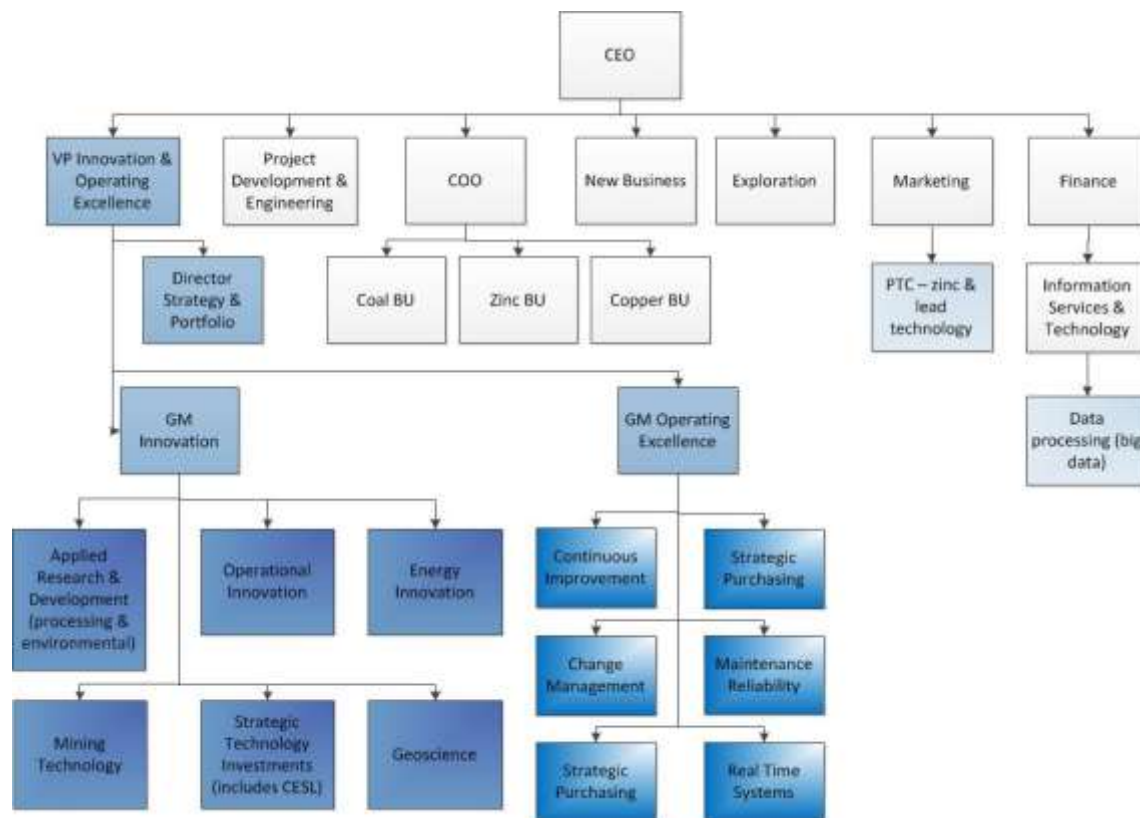


Figure 18: A Potential Organizational Structure for Innovation and Operating Excellence– Source Author

The focus of the coalition has to be on bringing support groups and key business units together to make changes. While the guiding team can start off small, it needs to grow significantly before progress can move beyond creating and communicating the vision. Key groups include:

- Business Unit heads – these people have direct control over the operations where these innovations will be implemented and set the direction for their group.
- General Managers of the affected operations – the GM's are held directly responsible for the operational and cost control of their operation and must buy into the changes for them to succeed.
- Chief Information Officer – the CIO and his team will be responsible for the implementation of many of the technologies and systems. They need to understand the requirements and information needs of each initiative and to guide the group in selecting the best technologies.
- The I&OE group and other technical groups – these groups contain a large number of technical resources and subject matter experts that can be used for both designing and implementing the initiative as they are able to work outside the day-to-day operational constraint.

Creation of an Innovation & Operating Excellence group brings much of the technical expertise required to drive change under one umbrella, and incidentally provides leadership for the guiding coalition who, since they are not part of the Senior Management Team, will necessarily operate outside the normal hierarchy. While this can be difficult, it is clearly necessary and the I&OE group provides a communication path needed to ensure clear and open transfer of information. To help this process, offsite meetings are useful to generate the required level of communication, understanding and trust to build the team. The selection of a strong leader to lead and interact with and be part of the Senior Management Team will be essential to achieve the power that will be required. Creation of a suitable governance model for innovation will ensure that successes and failures are reviewed and acted upon in a timely manner.

4.3. Creating a Vision

The most important aspect of creating change is creating the convincing reason for the change (Section 3.4.1) and having a vision that supports it; the greater the sense of urgency, often the easier it is to get support for the change. Similarly, the change will

not be successful unless those affected by the change can themselves envision where the organization wants to be and why this is critical to both the business and to them. Thus, not only do we need to expand the guiding coalition by convincing them but the employees must also believe in the strategies required to achieve the vision and are motivated by the outcome. To do this, we need to develop a picture of the future that can be easily communicated and understood by everyone from the board to the lowest level of employee. A vision is not about the numbers, it is about depicting a clear and compelling direction in which the company needs to go. While it may initially be rather blurry, it's the coalition's job to refine this over a period of time to be a clear and compelling story and able to be communicated in five minutes or less. As the vision becomes clear, the strategy for achieving it also needs to be developed.

Most people will assess the change based on what's in it for me (WIIFM). This is the time to reinforce the need to make a paradigm shift in the way we operate our mines, introducing automation and eventually moving away from the drill, blast, load, haul process if we are to radically improve productivity and further increase safety by separating people from equipment. The vision required for this transformation requires a change in culture, philosophy and work processes across the entire mining process from engineering to operations and maintenance. The introduction of new technology is not the vision, but is merely part of a strategy in increasing innovation. The vision focuses on the larger picture; implementing new more innovative strategies within Teck as a whole, to become more competitive and sustainable in the global markets that we operate in.

If we are to become more innovative, the company needs to have a well-defined technology and innovation strategy that has been approved and endorsed by the Senior Management Team and the board that truly articulates what we are trying achieve. This needs to be clearly communicated to all levels of the company.

4.4. Communicating the Vision

Communication is not a single meeting or a newsletter; it is about developing an ongoing campaign that not only reinforces the message but demonstrates through actions that the Senior Management Team supports the initiative (Kotter, 1999).

Therefore, communication requires an intense effort from everyone involved starting from the CEO and COO meeting with the operations management teams that will be involved in the transformation but at the same time using other mediums to deliver the same message to all levels of the organization.

While Teck does not yet have a technology or innovation strategy, we do have strategies around sustainability and development that will benefit from the development of an innovation strategy. These include being diversified, on the lower half of the cost curve and having long life assets. The sustainability strategy has six focus areas: Community, Our People, Water, Biodiversity, Energy, and Materials Stewardship. These focus areas represent the most significant challenges and opportunities facing our company in the area of sustainability (Teck, Sustainability, 2015) and rely on innovative approaches to deliver our short and long term goals. A technology strategy will create ways of working within the company that focus on sustainable development and balancing the triple bottom line.

Once the initial message is delivered, all available communication routes need to be utilized to deliver the message and demonstrate commitment to meeting the goals. These include the traditional crew talks, email, newsletters and the intranet but also social media such as Twitter and Facebook where Teck has a presence. It is better to be proactive than reactive in telling the story. Communication on routine items needs to be tied back to the transformation and comes in both words and deeds. Many organizations are creating their own YouTube channels for communicating to stakeholders.

The plan needs to be structured such that a quick win can be realized to show the credibility of the initiative and generate positive momentum. Success needs to show the effect on production performance, safety and relevance to the workforce. It is important in the change management process to continually link success and the strategies employed back to the overall vision at every opportunity, reinforcing the commitment to the vision. We must ensure that everyone is continuously reminded of what the transformation is and how each step is unfolding.

There will need to be a lot of sincere communication to win the hearts and minds of employees at all levels from senior management to truck drivers, for success

communicators need to be credible with the workforce and evangelists able to motivate. To be successful, evangelism requires three attributes; ability to *schmooze* - get out and meet people, make it easy to be in touch; *able to speak in public* – have something interesting to say, entertain, tell stories and thirdly *use social media* – share good news, offer information, analysis & assistance and be interesting using interesting visuals (eye candy) and drama to tell the story.

4.5. Remove Obstacles to the Vision

After communicating the strategy, which describes how we will become more innovative, there will be negative reactions from some parts of the workforce especially if there is a fear of job loss or drastic change in how people do their work. With successful communication though, employees can be emboldened to try new approaches, develop new ideas and step up to be leaders. The guiding coalition should be at the forefront of this process setting the direction that the program needs to go in. By incentivising people through their paycheck/bonus and showing how their jobs will be easier or more enjoyable, they will be more likely to embrace change.

Transformation inevitably raises fears and creates obstacles which need to be addressed as soon as they appear if momentum is to be maintained and opposition to the change isn't to get an audience. Sometimes these obstacles are in people's heads but they can also be real, such as in the organizational structure where job classifications can obstruct greater productivity. Fears need to be confronted openly and transparently so that we can negate backroom politics opposing the strategy; we need to ask how we do things differently to overcome these obstacles not just using the traditional methods but look outside the box perhaps to other industries (Section 3.3 page 26); where often the best innovative ideas are.

While these roadblocks may be identified early on and may be circumvented for a while, at some point they have to be confronted and removed. If the issue is a person then it is important from an ethical and workforce credibility perspective that they are treated fairly but at the same time action is essential to maintain momentum and show the credibility of the transformation.

Because of the scale of the process envisaged, any transformation will have to be phased across the organization rather than delivered to all operations in one fell swoop that is doomed to failure if for no other reason than the difficulty of managing such a change. It is important, therefore, to identify the implementation program in the strategy, picking operations that are both more likely to be accepting of innovation while at the same time presenting opportunities for quick wins. Introducing new tools and equipment in this environment creates excitement as these can be viewed as developmental opportunities for those involved.

Finding and using change agents (champions) in the various groups involved is critical, those who are genuinely interested and motivated to apply the new innovation will be critical to the process. At the same time, these change agents need to be credible members of their peer groups so that they can be strong resources creating momentum and support. Often, these people are viewed as being more credible than management. A critical need is always being able to understand why the changes are being made and what the overall impact is in the vision.

4.6. Creating Short Term Wins

Moving to a new strategy of innovation and technology will take time to roll out across all the operations and will risk losing momentum long before it is complete. While we all like to be able to declare victory at some point and move on to something else, broad transformational initiatives take a lot of time and effort to establish. Thus, it will be important to be able to establish some early wins (Section 3.6), where we can point to some tangible unambiguous benefits whether they are in lower costs, productivity, safety or sustainability. Quick wins are critical to successful change because they demonstrate credibility, attract resources and create momentum. Increased credibility can be used to continue the ability to change systems, structures and policies.

Celebrating the quick wins during this transformation is critical in maintaining motivation and encouraging the new behaviours the organization needs while also limiting the ability of resistors to build a power base. Demonstrating the tangible advantages of the new strategy should be recognized often, with rewards for significant

milestones and achievements. People are uncomfortable with change and fearful that innovation will cost them their job. In demonstrating the value of a new innovation, we need to show that by remaining competitive we are actually increasing overall job security.

Creating short term wins is different from hoping for them and thus it is important that the implementation strategy is structured to deliver benefits within a short time period and then thereafter at intervals rather than aiming for a big bang at the end. Picking suitable short term goals allows the work to be led and performed by a smaller team that can be picked to include the believers and change agents.

In order to demonstrate a compelling success story, it is important that baseline key performance indicators (KPI's) are carefully selected and understood prior to starting. This ensures that the new strategy can be effectively measured against the baseline to show success. While these KPI's will vary for individual initiatives, it is important that they contribute appropriately to the overall goal of increased productivity, quality, cost and throughput, etc. Some important KPI's include:

- Cost per man hour
- Cost per tonne of saleable product
- Equipment costs per hour
- Equipment availability
- Quality of product
- Throughput per unit time
- Value/amount of daily product

Frequent communication using appropriate KPI's allows progress toward the planned goals to be demonstrated on a regular basis reinforcing the value of the change. As mentioned in Section 4.3, the ability to build these improvements into a story helps people internalise the good news aspects of the change. While many of these new technologies have the potential to reduce manpower, given the current demographics at

many of our operations it is often possible to accommodate these changes in the natural turnover of the workforce.

4.7. Sustaining the Change

It is important to recognize that culture change and transformation take many years before they become sustainable, declaring victory too early can be catastrophic to the project. As discussed earlier, HVC implemented Mine to Mill in the 1990s and saw significant production improvements but ultimately even after seven years of success, the transformation was not embedded into the DNA of the organization and thus was not sustainable. To make a transformation sustainable, management needs to communicate and act in a manner consistent with the ultimate goals of the transformation.

As personnel change, it is important that new employees have values consistent with the strategy. As time goes on, it will be necessary to recreate a sense of urgency and reinvigorate the vision such that the message remains fresh. As members of the guiding coalition change it is important that they continue to embody the same values and power that the original team had such that they remain able to lead the transformation. Hasty declarations of victory will lead to the disbandment of the guiding coalition and may allow the forces of conventionalism to reassert themselves. Instead, the increased credibility from short term wins should be used give credibility to the value of the bigger problems. This allows systems that have not yet been tackled to be confronted and new goals set to further the transformation. As successes are achieved, it is important to listen to the workforce and take their feedback into account as employee motivation and support will improve when they believe they are part of the solution. Employees need to be engaged if they are to become part of the solution instead of the problem.

In time, there will be an increased belief that innovation and technology can deliver reduced costs and higher productivity. Taking the HVC Mine to Mill project as an example again, when HVC recently re-implemented M2M, it was fully 12 months before any change was derived and closer to 2 years before the first quick wins were

recognized and momentum for bigger innovations started to build but it will be many years before it becomes the new 'norm'.

4.8. Make it Stick – Institutionalizing the Change

Ultimately, the new paradigm of introducing technology and innovation on a large scale will move from transformational to sustainable and we will have a new norm of the way we do business. Articulating the connections between the new initiatives and organizational success helps to institutionalize the new approaches and create a culture of innovation. With success, new strategies become processes that are simply considered to be “the way we do things”. As with getting momentum in the first place, maintaining the change requires ongoing effort from management to communicate how the new approach helped to improve productivity and reduce costs, so that people continue to connect the vision with success. If we leave employees to connect the dots themselves, they often connect the wrong dots and come to inaccurate conclusions.

With time, the people who were instrumental in making the successful change will leave the company or move on to new jobs and a new generation will take over. It is important to make sure that the new generation fully embraces the new techniques and understands that innovation is the lifeblood of the company if it is to continue to compete successfully against other mining companies that are equally driven to increase productivity and control costs. In a world of ever faster change, management and the Innovation group must continuously seek and evaluate new technological advances to determine how these might further improve the efficiency and effectiveness of the organization and provide opportunities to further improve operational performance, while remaining true to the vision. It is important to also include a process of knowledge retention to encourage employees to remain with the company but also to capture skills and knowledge as they eventually leave.

Finally, it is important to understand and believe the value that the program can deliver as management's focus shifts to new challenges. As commodity prices rise again on the next cycle, companies will once again focus on increasing production even at the expense of increased costs and lower productivity. Sustainability requires that

succession decisions at the top of the organization are congruent with the vision. Although a successor may not be a resistor, if they are not passionate and willing to be a champion, interest will wain as the strategy is no longer foremost in the minds of the Senior Management Team.

Chapter 5. Conclusion

The final Chapter of this report will provide the conclusions and recommendations for the creation of a technology and innovation vision and strategy for Teck. Recommendations relating to the successful advancement of the transformation are outlined.

In common with many mining companies, Teck has focused on improving productivity through cost cutting and incremental improvement which has led to some modest, short-term results. Teck needs to be a leader in operational efficiency if it is to effectively compete against competitors with better ore bodies and lower distribution costs. We will never get an order of magnitude increase in NPV through piecemeal changes; big changes require a holistic approach. To make longer term and significant improvement, we need to move beyond single or point solutions, taking a broad view and adopt end-to-end value chain solutions to transform our business. We need to optimize each part of the business, not individually but as part of an overall business system. Systems integration is a key challenge for improving productivity; Teck needs to take an approach that breaks down the silos and takes a perspective across the entire process stream. This can be achieved by changing Teck's culture to empower employees and be encouraging of new innovative solutions to existing problems; using data and technology to support this.

Whether in the current low price part of the cycle or in a more normal market, Teck should continue to pursue a goal of cost control and low unit price; the difficulty is making a paradigm shift in operating cost while gaining more than a fleeting advantage over its competitors. The application of new technology and innovation is a potential way to achieve this. Among others, Rio Tinto and to a lesser extent Anglo American have made this a core strategy and the opportunity is there for Teck to follow. To be successful in making this transformation, Teck needs to develop a vision and strategy

that supports an innovative culture. A new structure is needed that brings together the majority of its technical expertise in a unified group under a leader that has membership of, and influence with, the Senior Management Team. Combining Innovation and Continuous Improvement will create the opportunity for a coordinated effort of both incremental and transformative change.

Only by changing our culture to one that encourages and supports innovation will we be able to achieve end-to-end transformative change. While technology and innovation can help break down silos and enable new working practices to evolve, only with good data can companies understand what good performance looks like. To achieve this goal, we need to create a culture of innovation, much as we have created a culture of safety through Courageous Safety Leadership. While seemingly daunting, identifying new technologies or innovations is the easy part. The greater challenge becomes the change management aspect of the implementation of the proposed solution.

People play a critical role in any transformation and Kotter's 8-Step model provides some clear guidelines for the stages that are required to achieve a successful change. Teck's use of the Prosci model provides a proven methodology to achieve the desired change and aligns well with Kotter. Key points to be born in mind include:

- Engagement and motivation of employees.
- Alignment of productivity measures with reward.
- Ongoing management of employee talent to ensure alignment with the strategy.

Implementing Continuous Improvement has required a cultural change to be successful; moving this forward to a culture of innovation can be a natural progression. Combining Operating Excellence with Innovation will promote the sweeping change required both at the macro and micro level. It will be through a combination of new innovation and continuous improvement that Teck will be able to make the gains required to remain competitive in the future.

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